Economic and Environmental Risk-Benefits and Guidelines of Harnessing Energy from Biomass and Wastes: A Case of Jamaica

By

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SUBMITTED TO THE DEPARTMENT OF URBAN STUDIES AND PLANNING IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF

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ABSTRACT

Is it possible that harnessing direct solar energy may generate less all-encompassing environmental and economic benefits than harnessing the same solar energy at a different level such as in the form of biomass? Is it possible that, when workers hate any change to a new technology, introducing even more advanced technology in another industry can change their attitude? Can a change in semantics used in engineering change the conventional argument of food versus fuel, increase export and reduce trade deficit? Can a systematic burning of biomass discourage deforestation? Can use of biofuel in automobiles conserve marine life in sea?

These questions and issues emerge from the analysis of the "energy dilemma" of the tropical island of Jamaica and that of the world which is made up several islands known as continents. The dilemma is that, if the sun is the main source of all energy, then at which level between the sun's direct rays and their conversion to biomass (plant and animal matter) or, a million years later, to fossil fuels should its energy be tapped? For energy-deficit developing countries, this dilemma becomes even more complex with the added dimension of economics as the import of energy (fossil fuel) increases their trade deficit, debt and decreases their ability to pay for its import, its use creates pollution, thus making the dilemma multidimensional.

Most of the literature deals with these questions and issues separately as an energy, environmental or economic problem; this thesis attempts to resolve them by integrating the three. All these interwoven issues and criteria are best illustrated by the context of Jamaica. The problem is that Jamaica needs energy today at the lowest cost so as to reduce its energy import and trade deficit and without any adverse environmental consequences in order to sustain its development. It cannot wait for a million years till its available biomass become fossil fuel.

This research shows that it is technically possible, economically feasible and commercially viable to generate electricity, biofuels and other products from biomass in Jamaica by using advanced technology. However, it would require removal of several barriers but the biggest constraint is that of declining production of useful biomass. This decline is due to many reasons but chief among them, as my fieldwork indicates is the lethargic attitude of farmers and workers which is reflected in the varying productivity of this biomass per acre since 1610. Historically, they have hated this biomass and call it a "whitemen's crop". They hate any change or mechanization which produces more of this biomass for whitemen.

When workers hate mechanization, can an introduction of even more advanced technology using advances in aircraft jet engines, biotechnology and bio-process engineering change their attitude towards the biomass? The question then is, can the use of advance technology and indigenous resource utilization be the reasons for fuel substitution for energy generation? They can be and such a form of energy generation would require implementation of an Integrated Energy Industrial and Agricultural System (IEIAS) with the public and private partnership as an inevitable component of such an organizational structure.

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CHAPTER 1 INTRODUCTION

1.1 Energy, economic and environmental dilemma

If the sun is the main source of all energy then at which level between sun's direct rays to their conversion to biomass (plant and animal matter) or a million years later to fossil fuel (coal and oil) should its energy be tapped ?

Is it possible that harnessing direct solar energy may generate less all encompassing environmental and economic benefits than harnessing the same solar energy at a different level such as in the form of biomass ?

Hence when, where and how much to generate, how to generate, how to store, how to distribute and how to supply energy on demand is a dilemma for any country in its energy planning and related policy issues.

In the global energy context, this dilemma becomes particularly important when examined in light of current energy use, its future increasing demand, and future decreasing supply (Davis G. R. 1990).

However, only the future decreasing energy supply as a case of resources depletion should not be the only argument for substitution of any energy source, even the advancement of technology can be the driving force behind substitution (Tabors R. 1990). Future energy systems need to be flexible so that new technologies can be adopted (Tabors R. 1990) in capturing energy at levels and efficiency not accessible before.

For developing countries this dilemma becomes even more complex with the added economic dimension as the import of energy increases their trade deficit, debt and decreases their ability to pay for its import.

Can developing countries in order to avoid the import of energy, to sustain their development utilize the new technologies and New and Renewable Sources of Energy (NRSE) such as solar, wind, tidal, hydro, biomass and demand side management (DSM) ? If so which one of the NRSE can be considered in a given context ? and why ? In summing up, capturing energy require consideration of technology, level of energy, resource availability, energy and economic efficiency.

All these interwoven issues and criteria are best exemplified by the context of Jamaica as described below.

1.2 Case of Jamaica

Jamaica is an island which imports fossil fuels (crude oil) for energy generation while it has the potential and an acute need to become energy independent.

Policy: This policy of import based on need, makes Jamaica dependent on imported fossil fuels while potential energy flows existing in its natural and man made environment are not fully harnessed through the use of NRSE.

The problem: Import of fossil fuels drain Jamaica's foreign exchange reserve and increases trade deficit and debt. In addition, its harbors such as Kingston and bays such as Port Antonio are being polluted by waste and by use of petroleum products. These pollutants are spreading in sea water and polluting its pristine bays and beaches.

Environment, economic and energy consequences: Jamaica's natural beauty is its wealth from which it derives foreign exchange earnings. The destruction of Jamaica's environment will jeopardize its economy which will further heighten its energy problems.

Interwoven problems of economic, environment and energy: For example, currently two ethanol plants in Jamaica produce ethanol extracted from biomass and export it to USA, while Jamaica imports petroleum as domestic energy input, and does not use ethanol in any form. At the same time scientific literature shows that biogas, biofuels and other forms of energy can be produced from solid waste, agricultural wastes and biomass; all of which Jamaica has in abundance.

Basic questions: My basic questions are: Can Jamaica use energy from biomass and other wastes efficiently ? Will it help in sustaining its economy and environment ? Has it ever used biomass for energy on a large scale ? Will it reduce its import of crude oil and thereby reduce its trade deficit ? If yes, then to what extent ? How can it do so ? Why should it do so ? Which lessons can be learned from the example of Jamaica for sustainable development which can be replicated in other countries with a similar context ?

1.3 Relevance and applicability

There are many countries with some similar context in which biomass can be utilized to different extent by using relevant biomass technologies, even if the country in question may or may not have biomass, energy or trade surplus as shown below.

Table 1.3

	Energy	Biomass	Trade	Examples	Form of biomass
Group 1	deficit	deficit	deficit	Mali, Chad	Animal matter - waste
Group 2	deficit	surplus	deficit	Jamaica	Plant - animal matter and waste
Group 3	deficit	surplus	surplus	Barbados	Plant - animal matter and waste
Group 4	surplus	deficit	surplus	Kuwait	Waste
Group 5	surplus	deficit	deficit	Egypt	Plant - animal matter and waste
Group 6	surplus	surplus	surplus	Malaysia	.Plant - animal matter and waste
Group 7	deficit	surplus	deficit	USA (OECD)	Plant - animal matter and waste

Source: author

For these countries how to use biomass and wastes still remains a dilemma.

1.4 Research issue

My research addresses these policy issues and dilemma, and at the same time questions the conventional notions that biomass is a low level energy carrier, that it creates harmful environmental effects, and that it leads to deforestation. The purpose of this research is 1) to show that indegenous resource utilization and taking advantage of advancement in technology can also be the criteria for using NRSE and 2) to examine the case of energy deficit but biomass and waste surplus countries such as Jamaica for the potential of generating energy from biomass and to discuss various related issues, barriers, constraints and opportunities.

1.5 Significance of research

Most of the literature deals with these issues separately as an energy, environment or economic problem; this attempts to integrate the three.

Most of the literature has also argued that biomass is a low level energy carrier, that it generates pollution, and that it is a traditional fuel for combustion mainly used in the rural areas in developing countries.

This normative view needs to be revisited in a global energy context and in view of the fact that specific forms of biomass can be a higher level energy carrier but may require simulation in a country context.

1.6 Global energy context

Currently 78% of the global energy demand is supplied by fossil fuels. Future demand of world energy consumption is going to increase by 50 to 60 percent by 2010, at the same time present consumer habits and ways of life may not change (Davis G. R. 1990). The current production, use, transport and rate of consumption of fossil fuel is a potentially destructive force to the environment. On the supply side, the remaining quantity of fossil fuel is equivalent to 10 trillion barrels of oil which is enough to last for 170 years at the present consumption rate (Davis G. R. 1990). With such a trend, and supply side scenario which route must be followed in energy planning ?

There are two views regarding possible routes to the future energy scenario. First is the "consensus view " which rests on keeping a status quo on current energy production, and consumption (case of Jamaica). Second is the "sustainable view", which presumes that environmental issues will become a priority issue in the international agenda (Davis G. R. 1990). Underlying both views and scenarios is the assumption that the world population will increase to 7 billion and the GDP of the world will have to double to sustain that level of population.

To sustain such a population explosion, energy will be needed and hence the search for alternatives or New and Renewable Sources of Energy (NRSE) will be necessary. It is in light of this sustainable view that I am examining a case of Jamaica to show the role NRSE can play.

1.7 Importance of NRSE

The major advantages of NRSE are that they are diverse, renewable, abundant in supply, available in a local environment, cost is almost free at source, small scale in size, decentralized in nature, and cleaner in terms of environmental hazards (Table 1).

Relative abundance or scarcity of NRSE may vary from region to region, hence NRSE are context dependent. For example Kuwait has no biomass and certain parts of Finland remain dark six months a year so those parts cannot use the direct solar energy. However this context dependency may be eliminated by scientific advances.

There are environmental and other issues with renewable energy sources and not all of them are inherently pollution free; but there exists wide choices of technology make them viable and cleaner.

1.8 Importance of biomass among all NRSE

I have chosen biomass because it has enormous energy potential; chapters three and four discuss the reasons for this extensively.

Biomass (all organic matter) is used extensively due to its availability and low cost, but its inefficient utilization can lead to deforestation, air pollution and health problems. Refuse, solid waste, municipal solid waste (MSW) are not biomass but they contain biomass, hence I differentiate between them for the purpose of utilization.

Efficiency in the utilization of biomass can be increased if new technologies are introduced into the existing energy generation program to generate energy in the form of liquid fuel, gas and electricity. New technologies have become available due to the advancement in aircraft engines, biotechnology and bio-process engineering making biomass a higher level energy carrier [Davis G. R. 1990]. The advance technologies which utilizes biomass have to be simulated in an actual country context which has not been done.

1.9 Reasons for selecting a country for a case study

My reason for choosing a specific country for a case study is that biomass and wastes are physical quantities, and assessment of their geographical distribution and availability in that country are crucial in order to justify their use in energy generation in that particular country .

The reasons and criteria I used for country selection have been stated below. My criteria were as follows 1) energy problems (supply) such as energy deficit, oil import, 2) energy problems (demand) such as high population, high energy demand 3) biomass surplus, high potential for generating energy from biomass and other NRSE such as solar, wind, hydro-power power, tidal power etc. 4) economic problems such as national debt and trade deficit, 5) environmental problems such as pollution, waste, municipal waste etc. which can affect its natural environment and tourism industry. I could have selected countries such as Thailand, Caribbean islands, Bali, Vietnam, Cambodia, Tanzania, Kenya etc.

I have chosen Jamaica because Jamaica fits all of the above criteria, in addition it is an island which simulates the world which is made up of several continental islands on earth.

1.10 Preview of sequence

I shall first examine the potential of generating energy from biomass and wastes from literature. Then I shall review current energy and economic context of Jamaica, its future plans for generating energy, and compare biomass with other NRSE. Then I shall examine whether Jamaica has sufficient biomass resources and whether it has ever used them, and whether it has invested in any project involving biomass utilization. Then I shall compare the use of oil versus the use of biomass in general and in Jamaican context. Next I shall suggest an alternative arrangement for energy generation using biomass and determine its location in Jamaica based on the demand, transmission and distribution constraints. Next I shall identify barriers and "what if scenario" in its implementation, and evaluate the proposed alternative path. From the evaluation and analysis I shall draw conclusions and then propose recommendations which can resolve the barriers. In the last part I shall draw lessons which can be relevant to its applicability in other countries with similar context.

CHAPTER 2 METHODOLOGY

In the previous chapter I presented a case of Jamaica where energy, environment and economic problems are interwoven. The question is how can they be examined and resolved in a manner that, takes into account various dimensions together rather than in isolation ?

To examine the interwoven problems of Jamaica in an integrated manner, I adopted two methods. The first one involves input/output analysis and cost-benefit analysis. The second one is based on my own method and terminology from my earlier thesis "Cybercolibrium" [1] (Joshipura J. 1977).

2.1 Black box and the translation mechanism

I consider the island of Jamaica a physically and hence functionally finite system "a black box"[2] which may have a need to sustain itself by using its own resources or balancing its inputs-outputs. If it cannot, then it has to obtain external inputs by importing goods and services by paying out payments in hard currency which has to be obtained by exporting goods and services (outputs). Payment or receipt of hard currency can be measured in exchangeable goods and services. It acts as a translation mechanism where exchange rate is the value of "translator" (Joshipura J. 1992). This relationship based on exchange mechanism causes input and output to affect each other.

2.2 Black (opaque), Gray (translucent) and White (transparent) boxes

Jamaica remains a "black box" [Wiener N. 1948] to me, as long as I do not study its internal organization and external environment, but as soon as I begin to study and understand its internal organization, it begins to become a "gray box". If I am able to understand its internal organization completely then it becomes a "white box" or a transparent box. However this task is impossible, which sets the range of my knowledge between the black and the white box (Joshipura J. 1977).

2.3 Elements of boxes

1 A word derived by myself from cybernetics, ecology and equillibrium [5]
2 Black box - whose internal organization is unknown [3].

I consider various barriers, subsidies, taxes etceteras as filters which filter effects which would have been present in the Jamaica in the absence of any filters. Tax incentives or reduction of duty is equivalent to reducing the size and or porosity of filter. Laws are then regulatory mechanism which forms a contextual environment imposed by the Government or any regulatory authority (regulator).

2.4 Efficiency ratios

In terms of energy and economics, higher the ratio of output to input, the better it is, which means you get more output per given input. Maximization of output determines the efficiency of the system which is inside the black box along with its relationship to the external environment. Ratio of 1 then represents a state of equilibrium of the system. Ratio of higher than 1 is better, as it creates a reserve which acts as a buffer which can be utilized when the system[3] deviates from its state of equilibrium at which output equals input.

However it should be noted that, in case of electricity the ratio of 1 may be achieved in theory but higher ratio than 1 cannot be achieved because there is always an energy loss associated with energy conversion (LaBel P.1982) and therefore the goal is to achieve ratio closer to 1.

In case of economic input-output higher ratio than 1 can be the goal.

2.5 Facts and Task

Jamaica at present cannot balance its enenrgy and economic output to input ratio. Currently this ratio is less than 1 which means it requires more energy and economic input to produce output. My task then is to identify those filters or mechanisms which can or does distort or alter the values of certain variables or translators affecting the ratio to be less than 1. Then recommend correction in the system which would bring ratio to 1 or higher (except electricity). Then present a simulated scenario to show how the system will behave under my recommendation.

2.6 Process

To simulate scenario I have used input/output tables showing flow of 1) material 2) energy and 3) funds.

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3 Economic and energy are dynamic systems

I have prepared worksheets 1 to 6 to show analysis of costs and benefits along with discounted cash flows projected over fifteen years. In these worksheets I have kept cost constants and varied time and alternatively kept time constant and varied cost.

I have not used shadow prices based on exchange rate as Jamaica's currency is freely convertible but used world market prices [Roemer M.][Jenkins G., Harbeger A. 1992] instead of subsidized prices to show that proposed alternatives can work under market conditions.

Then I have evaluated the alternative for different conditions under which it may fail (sensitivity analysis) and what are the precautions required or under which conditions it will succeed. This sensitivity analysis will take into account different variables such as supply, demand, price variation and climatic effects.

My task is to show under what sort of environment and which sort of policy framework will the proposed alternative succeed. The conclusions are based on evidence from my fieldwork, literature and the analysis that follows.

Summary: In this chapter I have shown that I consider Jamaica as a physically finite system which needs to sustain itself by balancing its input-output ratio to 1. I consider it as a black box because its internal organization and external environment is not known to me, hence I need to study it so that it becomes a gray box. I use input-output analysis and cost benefit analysis to test my proposed alternative which can help balance the input-output ratio and then make recommendations.

In the following chapters I shall apply this methodology beginning with analysis of energy, economic and environmental context presented in chapter 3.

CHAPTER 3 ANALYSIS OF ECONOMIC, ENERGY AND RESOURCE CONTEXT

In this chapter I will highlight the central role that energy plays in Jamaica's economy and more specifically I will link Jamaica's energy program to its import, export, trade balance and debt. I shall present a rationale for focusing on energy and alternative energy sources. Next I will identify possible economic and energy options available to it. I will conclude by presenting a brief survey of biomass resources of Jamaica as they relate to energy.

3.1 The problem definition and approach for Jamaica as black box

The basic question is whether Jamaica can sustain its economy, energy and environment by using either imported or indigenous energy resource. As per my methodology described in chapter 2 this would require having an aim to study the black box namely " Jamaica" till it becomes a white box.

3.2 Economic context of trade deficit and debt

The major problem that Jamaica faces is that it has a continuous negative trade balance from 1987 to 1992 and a debt which has accumulated to US $3878 million by 1992 [EESJ 1991].

Ever since Jamaica became more closely linked to the outside world with the introduction of SAP[4] and free floating currency in 1990, its economy has become even more vulnerable to the volatility of global currency and energy markets [ESSJ 1991].

The volatility in energy markets affects Jamaica's economy even more as Jamaica is an energy deficit country. It imports because it depends on imported energy and relies on export revenue to pay for all of its energy import. How does it continue importing when debt is accumulating ?

3.3 Two possible options to resolve it

To be able to reduce debt and to pay for imports it has to balance the trade and to do so Jamaica has two possible options with their associated consequences.

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4 Structural Adjustment Program [9]

The first alternative is to increase the export of its major exportable commodities (traditional and nontraditional). Its major traditional exportable items are bauxite, alumina, manufacturing and sugarcane products. But this would require increasing production of exportable items which in turn would require additional energy to produce them as table below shows where I have classified each export as consumer or producer of energy.

Table 3.3

	Major export commodities & services	Value (US $000) (1991)	% change since 1990	As a % of total exports	Energy consumer or producer	Long-term prospect
1	Alumina	$ 542,959	- 13.17	47.11 %	Consumer	Bleak because noncompetitive
2	Non traditional	$ 221,467	- 00.94	19.33 %	Consumer	can be bright if competitive
3	Bauxite	$ 112,913	09.65	9.85 %	Consumer	Bleak because noncompetitive
4	Sugarcane	$ 087,446	01.96	7.63 %	Producer	Inefficient but bright prospects
5	Bananas	$ 045,109	19.68	3.93 %	Producer	Bright-can be made better
6	Dehydrated ethanol	$ 018,000		1.57 %	Energy equivalent	Depends on local production Efficiency, EEC & CBI terms
7	Rum	$ 015,444	- 10.18	1.34 %	Consumer	Bleak - competition
8	Coffee	$ 011,982	25.74	1.04 %	Producer	Increase in production and price
9	Molasses	$ 009,000		0.78 %	Consumer	Supply determine demand
10	Cocoa	$ 004,752	- 25.07	0.41 %	Producer	Price and production decline
11	Citrus	$ 004,453	- 50.26	0.38 %	Producer	Price-production decline
12	Pimento	$ 003,544	- 35.61	0.30 %	Producer	Price and demand decline
13	Gypsum	$ 000,551	29.65	0.04 %	Consumer	No data available
	Total %			93.71 %		
12	Tourism	$ 721,000				Depends on stability, currency

Source: Produced by author based on the information from Economic and Social Survey of Jamaica 1991 published by the Planning Institute of Jamaica 1992.

The second alternative is to decrease imports which amounted to US $1799 million in 1991 and exceeded exports of US $1145.2 million by US $654 million creating net negative trade balance. Its major import items with 1991 values are machine, transport equipment (US $460 million), crude oil (US $327 million), manufactured goods (US $288 million) and chemicals (US $223 million) [EESJ 1991]. But increasing the imports of any of the items other than energy will require more energy, and decrease in their import will require less energy but it will still not eliminate reliance on external energy.

3.4 The role of energy in an economic context

Energy plays a significant role as the second biggest import item (US $327 million) which constitutes 18.18% of imports (US $1799 million) and consumes 28.85% of export revenue of

(US $1145.2 million), and when added to its debt service payment of US $611 million, it equals to 81.92 % of its total export revenue in 1991 [EESJ 1991].

This is shown in the worksheet 1 section M & section N. This worksheet shows the proportion of oil import to the total import and export projected over fifteen years. Depending upon the price of oil, cost of oil import can reach as high as 50% of the revenue generated from export. This could very well happen if there is a sudden price rise. Such a set of economic scenario can bring Jamaican economy to a grinding halt. Hence it is not a matter of choice but inevitable that Jamaica turn its attention to reduce imports.

But any overall import reduction would require reducing the amount of imported energy. Reducing import of energy would require reducing import of crude oil (US $327 Million), which is extremely difficult if the current energy context is examined.

3.5 Energy context and its demand on economy

This is because currently Jamaica imports 99% of its energy needs in the form of crude oil derivatives. Oil fired plants generate 98% of its electrical energy.

In addition, energy demand is growing at about 6% per year with peak demand expected to rise from a current level of 340 MW to 670 MW by 2007. In 1992, actual demand growth was 7.3% but achieved growth was only 4%. [EESJ 1991].

While energy supply is dependent upon the current public electricity system with an installed capacity of 495 MW, it will need expansion to meet the growing peak demand.

Most of the peak demand is centered around Kingston (55%=190 MW) and Montego Bay (21%=71 MW) where the strongest growth is expected because of tourism. Most of the industrial demand will come from the Kingston area [EESJ 1991] (see map 1 -TPP93[5] Project, Spring 1993).

Electricity supply cannot be obtained from the power grid of other adjacent countries as Jamaica is an island surrounded by the Caribbean sea. Electrical supply also cannot be substituted by other attempts at using renewable energy sources such as biogas[MMEJ](Interview -2) or solar

5 Technology and Policy Program

heater on rooftops, because none of them have succeeded in generating energy at a large scale [MMEJ 1992].

This leaves oil as the only energy source, which affects Jamaica's economy with its characteristic volatility of supply and prices.

3.6 Future plans to generate energy for future demand

To overcome the problems of volatility of price and supply associated with oil, Jamaica Public Service Co. is planning to use imported coal instead of imported oil. As its supply may be more reliable JPS[6] plans to replace current oil fired plants with 400 MW of coal fired plants over next 15 years [Norris Thomas 1993]. Although the price of oil is relatively stable in recent years.

Future plans of replacing oil will still not resolve the problem of trade deficit and debt as long as the coal is also imported.

The only significant change will be that the Jamaican power system will be extensively privatized in future with the exception of transmission and planning under "utility control". It is anticipated that all the new capacity of power supply will be supplied by independent plants; however, which energy source they will use is not known.

This brings the choice to a second alternative, that is, to reduce trade deficit and debt by increasing exports of its major exportable commodity such as bauxite-alumina, manufacturing goods and sugarcane products.

3.7 Assessing international market potential for exports to pay for energy import

The market potential for fuel grade ethanol, sugar, molasses, coffee, banana, bauxite and alumina is bright. For example, currently the market potential for fuel grade ethanol in US is at 61m usg and projected to expand to 208 m in 2001[page A-204, UNDP report]. For molasses export prospects are also bright as the demand of molasses depend on the supply of it. [OECD 1978]. Sugar earned the highest export revenue among all agricultural exports in 1991 [EESJ 1991] and the World sugar demand is expected to grow by 1.5% per year [Williams R. Larson E. 1993].

6 Jamaica Public Supply Co.

Can Jamaica take advantage of these bright prospects ?

3.8 Indirect role of energy in export competitiveness

Although market prospects for exports of bauxite, alumina and manufacturing products are bright, exports of major export revenue earner bauxite-alumina (US $654 million) and non traditional-manufacturing (US $221 million)[EESJ 1991] are declining.

I found that energy as an input in these industries again plays a significant indirect role in their decline. The reason for the decline is the high cost of oil based energy as an input in bauxite and alumina. Bauxite ore is refined to alumina and alumina is reduced to aluminum and this process require extensive energy. Bauxite and alumina industries imported in 7.4 million barrels of oil for its energy needs at a cost of US $ 96 million in 1991 [EESJ 1991]. Although the production has increased in last few years, the prices of bauxite are stagnant. This is because it is more profitable to turn it into alumina before exporting it. This method shrinks the volume to be transported, and saves the transportation cost but if the energy cost in transformation is high then the savings in transportation will be nullified. The countries which export alumina competitively are those with low cost energy producers such as Canada, [Knight-RIdder 1987] while Jamaica is not a low cost energy producer.

3.9 Unreliable export revenues of other export items

Export revenue from other items such as sugar and fuel grade ethanol are unreliable. This is because although sugar earned US $ 87 million in 1991, it cannot be relied upon since the revenue that it brings is based on the fixed quota which cannot be increased by Jamaica. US-EEC subsidizes the imports of Jamaican sugar under a fixed quota system at an average price of US $393/ton [EESJ 1991] compared to the international market price[7] of US $266/ton.

Jamaica exports dry fuel grade ethanol and earns US $18 million (liquid biofuel - one of the energy resource from biomass) again under CBI[8] at a subsidized price after dehydrating it from wet ethanol obtained from EEC also at subsidized price. I learned about it in interview (6,10) January 1993 and reconfirmed in August 1993 [13b](UNDP report).

7 The Financial Times. August 1993.
8 Caribbean Basin Initiative - to promote economic development.

The only positive but insignificant role that energy plays is in the exports of refined crude oil products which amounted to US $11 million or 1% of exports in 1991[ESSJ 1991]

In all other sectors high cost of energy affects export sectors and industries. A decline in major industry, manufacturing or agriculture can create unemployment, social unrest and all other destabilizing effects which can further affect other sectors of economy such as tourism.

3.10 Tourism can be affected by industrial decline, unemployment and unrest

Tourism is one such unreliable sector which can be affected by a situation decribed above. Currently Tourism has been booming since the decline of Jamaican currency. Tourism to Jamaica has increased over the past year, but Jamaica is not the only tourist attraction in the Caribbean region. The only advantage it has obtained recently is that the Jamaican currency has reduced in value against major foreign currencies after it became 100% convertible.

Tourism as a service industry may bring more revenue but that should not be used as a reliable source of revenue for import. The reasons for this argument are many. First, other countries such as Cuba with a lower costs are entering the tourist market. Second, increase or decrease in influx of tourists depends on the strength of the economies of other countries. Third, tourism employs less people compared to agriculture, industry, service, trading, and transport sectors. A weakness in these sectors can create unemployment, social unrest, instability and can ultimately affect the tourism, so protecting all export sectors in a comprehensive manner may be necessary. Hence the analysis above on a sector by sector basis was necessary.

3.10 Complex problem of Jamaica - the "gray box" :

Hence the complex interwoven problem is: How can Jamaica decrease its trade deficit (US $654 million) and still supply increasing demand of energy (500 MW) at less than the current 5 cents/kWh cost [MMJ 1992], so that the cost of energy as an input in export industries such as bauxite-alumina goes down making them competitive allowing them to increase export revenue to help decrease Jamaica's debt (US $3878 million)?

3.11 Why focus on energy?

The rationale behind the focus on energy is that it constitutes a major import cost and cannot be paid for without corresponding increase in exports, but the exports themselves are affected by the high cost of energy.

3.12 Why focus on alternative energy sources ?

The rationale for seeking alternative energy resources is that Jamaica is deficit in energy, so it imports, debt is created, and since energy forms significant percentage of expenditure, while making other exports non competitive, Jamaica needs to look for alternative, indigenous, and cheaper energy resource.

Hence the import of oil cannot be reduced till Jamaica finds one or more significant and sustainable alternative energy resources.

There are several NRSE such as solar, wind, hydro, biomass and demand side management (DSM) which have to be assessed for their potential. For this purpose a comparison was carried out in general between various NRSE such as wind, solar, biomass, hydro and DSM with reference to Jamaica (TPP93 project[9], May 1993). They were also compared with current energy use and the proposed JPS plan in the same project.

The assessment resulted in concluding that biomass has the highest energy potential to produce energy at a low cost.

Hence an options to use biomass exist, but it has not been exploited even when Jamaica has biomass in abundance as it is a tropical island. Hence, there is a need to assess its biomass potential and energy potential from it.

3.13 Biomass resources of Jamaica and landuse in Jamaica

Jamaica is a tropical island with the total land area of 2,816,000 acres of which biomass in the form of plant matter covers 90% of the area divided between dense tropical forest (44%) and agriculture (46%) which includes pastures [National Atlas]. Most of the forest cover is dispersed

9 TPP93 project under the direction of Prof. Tabors R. in which I examined the biomass resource. I had proposed this project to Prof. Tabors and my classmates to get a comparative analysis of other NRSE in Jamaica. Other authors examined other resources. Nick Maybe (wind), Kara Calahan (hydro), Beulah D'Souza (DSM), Tom Fiddaman (solar). Data then was fed into a software called " PowerPlan" for an interactive simulation model about electric power planning and results were obtained.

around the blue mountain range and in its valleys. There are about 4000 species of plants in Jamaica not including fungi and lichens. Principal species of forest include Santa Maria, Timber Sweetwood, and Yellow Sweetwood. There is also wet limestone and dry limestone scrub forest in different parts [National Atlas][National Physical Plan]. The rest of the 10% of the land is used for different uses such as settlement, mining and infrastructure etc. (see table 2).

Biomass is found in may forms and types in Jamaica. The climate in Jamaica is tropical. It rains at least eight months in a year and the average rainfall is about 100" a year. It is available in direct form such as in forestry products, forest residues, agricultural crop residues on the farms and plantations, as organic wastes. It is available in the indirect form in municipal solid waste.

Agricultural crops: Most of the major crops, with their share of land, are shown in Table 2. Sugarcane among all agricultural crops occupies the largest acreage up to 168000, or 6% of total land area among all plantation biomass [National Atlas]. The sugarcane crop and its related industries have been well established on the island for last several hundred years. The major products obtained from sugarcane and its derivatives are sugar, sugar molasses and alcohol, all of which are exported [EESJ 1991].

Barren dry land not good for agriculture occupies about 4000 acres or 0.1% of the total land area.

Experiments to grow Leucaena on barren lands in Jamaica have been carried out by a Jamaican private sector group called "Enerplan" has been successful [interview -3][Hales A., Minnot D. 1987]. They reported that they have succeeded in 1) building a commercial scale fermentation factory, and operated it using leucaena leaf mill 2) producing feed grade protein ingredients in a sufficient quantities to allow a reputable feed mill to produce whole feeds based on their ingredients and 4) completing feed trails. All these attempts have been supported by UNESCO, UNDP, and CARICOM.

3.14 Topographical requirements of agriculture

Most of the sugarcane, banana, and pineapple farms and plantation are located below the height of 500 feet on the relatively few flat lands, due to ease of access, and crop growth requirement [National Atlas].

3.15 Biomass in waste

None of the towns or settlement in Jamaica have sewage systems or waste treatment plants. Most of them including Kingston dump their sewage in the sea or waterways (interview -12).

Summary: Jamaica has the need to reduce import, trade imbalance and debt in which energy plays a significant role. Jamaica has abundant biomass which has a great energy potential. Then why is it that Jamaica does not use biomass for energy successfully? Are there any technology and fuel barriers? This would require assessing biomass to energy conversion technologies and fuels along with comparison with coal based power technology. I shall discuss this in the next chapter.

CHAPTER 4 ANALYSIS OF GENERATING ENERGY FROM BIOMASS AND WASTES

In the first chapter I outlined the global dilemma of capturing energy. I also presented the case of Jamaica, where this dilemma was best exemplified with the added dimension of economics and environment, making the dilemma multidimensional. In chapter two I outlined the methodology and strategy which I have adopted in dealing with the multidimensional dilemma. In chapter three, I further articulated the multidimensional dilemma of Jamaica, in which energy played a crucial role, affecting Jamaica's expected goal of achieving economic, energy and environmental sustainance. Then, I identified an inevitable need for using alternative, indigenous resources, preferably NRSE, and among the NRSE, biomass. Then I posed a question as to why is it, that despite the need and the biomass surplus, Jamaica does not use biomass for large scale energy conversion? Are technologies the barrier?

In this chapter I will assess technology to see if it is a barrier. First I will state the criteria which any resource or its relevant technology need to satisfy. Then I will describe properties of biomass and its relevant technologies. Then I will show, how the biomass technologies are better than the coal technology which JPS is planning to use as an alternative to the current oil fired plants. In the end, I will articulate the cost-benefits of using both current and proposed fuel resources and their relevant technologies.

4.1 Criteria of competitiveness

Any energy resource such as biomass can be competitive against imported fossil fuel if (1) its supply is reliable; its price and production cost of electrical generation is lower, (2) it is indigenous, (3) it satisfies growing demand, (4) it can supply the base load so that it can replace the fossil fuel based plants, (5) it has a higher conversion efficiency than coal plants, (6) it does not cause any negative environmental consequences and (7) it reduces transmission and distributive losses.

4.2 Biomass - properties

Biomass is all organic (plant and animal) matter, which has may positive characteristics for it to be considered as an energy resource.

Biomass (plant matter) through the process of photosynthesis harnesses solar energy most effectively by first collecting it at low cost, and storing it for later use. Hence the plant matter can be considered as a low cost solar energy collector and storage unit. Harnessing direct sunlight in comparison has a high cost of collection and storage and it is intermittent in supply [Hall, Rosillo-Cale, Williams 1993], which is not a desirable quality of an energy resource.

It is an organic carbon based material that reacts with oxygen in combustion and natural metabolic processes to release heat [Twiddle J. 1986]. Its chemical properties such as higher reactiveness than coal make it more attractive for thermochemical gassification for power generation.

It can be environmentally acceptable, if it is grown sustainably as it generates no SO_2 during combustion, instead it generates CO_2 which is extracted back from atmosphere by plants during the process of photosynthesis leaving no net build up of CO_2. In addition it causes no pollution as it generates less ash than coal, and its ash is free of the toxic metals [Hall, Rosillo-Cale, Williams 1993]. Its ash (char) can be further utilized as a fertilizer.

However there are constraints in its use.

Its physical properties such as low energy density, higher mass density and dispersed nature in comparison to coal would require that such power plants generating energy from biomass are installed at dispersed locations close to the sources of biomass so as to reduce transportation costs. But then which are the sources of biomass?

4.3 Biomass sources

Biomass is widely available for energy purpose in many forms. It is available in the form of residues from food, fiber, agriculture, and forest products industries. Biomass is also available from dung and municipal solid waste (MSW). It can also be available by harvesting forests, farms and plantations.

It can be grown in a variety of conditions such as degraded lands by selecting appropriate species based on the water requirements, soil conditions and availability of land. For all biomass resources, land and water are constraints which can limit its contribution.

It can be further classified for energy feedstock in terms of plantation of trees such as fast growing C_3 plants such as *Leucaena leucocephala, Eucalyptus* or herbaceous C_4 plants such as sorghum, sugarcane, or switch grass [Hall, Rosillo-Cale, Williams 1993].

Are the biomass-to-energy conversion technologies then as varied as the biomass sources ?

4.4 Biomass conversion technologies

There are many biomass to energy conversion and cogeneration technologies such as BIG/STIG[10] BIG/ISTIG[11] for electricity, Distillation and Solvent extraction [Extraction de Smet bulletin 1988] for biofuels, and so on.

The advantage of BIG/ISTIG is that the use of biomass as fuel requires no SO_2 recovery unit when compared with the coal plant. This saves steam which would have been used by the recovery unit and can be utilized for generating electricity [Williams R., Larson E. 1993]. The absence of SO_2 unit in the BIG/ISTIG plant design also reduces initial capital cost of installation. In addition cogeneration mode of BIG/ISTIG power plant also allows steam and / or electricity as the choice of energy carrier.

To operate BIG/ISTIG plant year round requires a constant supply of biomass fuel with an acceptable level of moisture content, depending upon the biomass.

Cogeneration technologies or gas turbines are available in the capacity range of 1 MW to 111.2 MW [Gawlicki S. 1993]. Plants with higher capacity would require biomass fuel from a larger area, resulting in an increased transportation cost which would make it uneconomical [Williams, Larson 1993].

Hence, the selection of biomass as fuel depends upon the reliability of supply such as renewability, predictable year round availability, ease of collection in terms of defined property rights which permits collection and easy access for collection such as infrastructure for transport and low transportation cost.

Biomass from plantations and farms compared to biomass from forests satisfies most of the above criteria.

4.5 Waste (biomass in waste) to energy conversion technology

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10 Biomass-integrated gasifier/steam-injected gas turbine

11 Biomass-integrated gasifier/intercooled steam-injected gas turbine

There are many types of wastes in which biomass in the form of organic matter is present, such as municipal solid and liquid waste, stillage from distillery and ash from power plants.

Waste treatment technology such as UASB[12] can treat the waste and produce other forms of energy such as gaseous fuels (methane and ethane), liquid fuels (methanol and ethanol) and other products (solid and liquid fertilizer).

The advantage of UASB technology is that it does not require any external energy input. Another advantage is that it can be installed at any scale and location [Lettinga, Haandel 1993]. In addition, it produces environmentally and economically acceptable and useful commodities.

4.6 Biofuels from solvent extraction - distillation

These technologies can also produce biofuels and industrial alcohol from biomass. They are produced as tertiary products during the production process of the primary product.

The use of biofuel for automobile use is still under debate despite the publication of a number of articles in 1993 and earlier depicting success of Brazil's and Zimbabwe's biofuel program. There has been recent policy support for biofuels which began with the Bush administration and which has been continued by President Clinton's administration.

However if the market is any indicator of biofuel's sucess, then the fact that the largest biofuel producer "Archer Daniel Midlands (ADM)" raised US $289 million within a week last summer on Wall Street suggests that market has confidence in the future of biofuels. Again, it should also be noted that in recent years the price of oil has been declining and has remained low at almost $15/barrel, and hence, to compete with gasoline at this price, Jamaican produced biofuels have to be really low priced.

Without adding to this debate I am presenting here only a technical comparison between ethanol and gasoline as described by Goldemberg J., Monaco L., Macedo I. in their article on "The Brazilian fuel-alcohol program". They state that " Ethanol has a research octane number (RON) of 109 and motor octane number (MON) of 90, both of which exceed that of gasoline, which has RON of 91 to 98 and MON of 83 to 90. It is possible to design an ethanol engine that runs 30% more efficiently than a gasoline engine. Ethanol has lower vapor pressure than gasoline, resulting

12 Upflow Anaerobic Sludge Blanket (UASB)

in fewer evaporative emissions. Ethanol's flammability in air is also much lower than that of gasoline which reduces the number and severity of vehicle fires. Anhydrous ethanol has lower and higher heating values of 21.2 megajoules per liter and 23.4 megajoules per liter, respectively; for gasoline the values are 30.1 and 34.9 megajoules per liter. The advantage that ethanol offers, including reduced emissions, will not however be maximized until engines specifically designed for ethanol become available ". Hence there are certain positive aspects of biofuels and yet its use is being debated because its price is higher compared to gasoline.

Next I shall outline the consequences if Jamaica decides not to adopt any alternative and continues the status quo by relying on oil and coal for energy needs, and compare those consequences with advantages of the alternative offered by biomass.

4.7 Comparison of biomass v/s continued reliance on oil

a) Costs of continued reliance on oil: Consequences of Jamaica's continuous reliance on oil are that high energy cost will affect its exports as I have shown, increase its negative trade balance and debt, it will remain dependent on volatility of supply and price (this is not true in last few years). High energy input costs will make its exportable items such as bauxite and alumina (the largest export earners) non competitive (This is true despite low price of oil because what is low is relative). Continued emphasis on imported energy sources may discourage development of indigenous energy resources and pollution created by the use of crude oil will continue. Pollution spill in its pristine blue waters will always remain a possibility, threatening marine life and tourism.

b) Benefits of reliance on oil: If Jamaica does not import oil, then its export of refined products (value US $11 million, 1% of exports) from refinery may suffer.

4.8 Price of oil or its short time availability as determinant factor

What if the price of oil declines so much that the production cost of electricity is less under oil than under biomass ? What if Jamaica discovers oil - unlikely but a wild guess? The discovery of oil as a determinant factor depends on the quantity of oil found. It can certainly help Jamaica in its export of refined products from its PCJ refinery [ESSJ 1991]. Decline in the price of oil can never be permanent and relying on it to make a major decision of not using indigenous energy resource may not be beneficial. In addition, whatever funds are spent on purchasing oil, it still drains the foreign exchange reserve of Jamaica whereas fuel from biomass does not. In addition, even if the oil is found, Jamaica needs to determine how far it is feasible to produce it, based on its value as per the prevalent world market price.

4.9 Costs and benefits of generating electricity from biomass

a) Cost criteria of using biomass to generate electricity (1) Jamaica may have to invest in BIG/ISTIG plants when the current oil fired plants are retired (investment- US 100 million)[Ogden J., Williams R., Fulmer M. 1990]. (2) If forests are harvested unsustainably for fuel, it may lead to deforestation. (3) Lower energy cost from biomass based energy generation compared to oil and coal may actually increase the demand for energy.

b) Benefits of using biomass to generate electricity: (1) The import cost of energy will reduce (2) The cost of energy generation may reduce. (3) This will reduce energy input cost for bauxite and alumina industries making them competitive, increasing their export and export revenue. (4) SO_2 generation will be eliminated and no net build up of CO_2 will occur [Williams, Larson 1993]. (5) Funds spent in purchasing oil to generate electricty would have gone to oil producing countries. If the electricity is prodcued from biomass the funds saved by not importing oil would remain in the Jamaican economy. 6) Decreasing oil use will decrease oil related pollution. 7) More people will be employed in Jamaica by using biomass fired power plant than a coal or oil fired power plant.

4.10 Constraints and benefits of biofuels from biomass

a) Constraints in generation and use of biofuels from biomass: (1) None of the vehicles in Jamaica are equipped to use 100 % ethanol, methanol or methane gas hence they would require re-engineering. (2) There may be unemployment in oil based industries unless the labor force finds employment in new biofuel based sector. (3) The biofuel industry will compete with alcohol industry for one of the raw material for alcohol and biofuel, known as sugarcane molasses. (4) Distilleries producing biofuels will produce stillage.

b) The benefits of generating biofuels from biomass: (1) It will reduce the import cost of importing petroleum for vehicles. (2) The funds saved by reducing or stopping import will go to those who collect and supply biomass to the distilleries which will produce biofuels. (3) The use of biofuels will create no air pollution [Goldmberg, Monaco, Macedo 1993] (4) Volatility of price and supply will not affect local economy.

4.11 Waste treatment facility

The constraint of using UASB technology is that it will require setting up of complete sewage collection system, investment, and land allocation.

Benefits: It can simultaneously treat stillage from the distillery and municipal waste. The end product of the UASB process is the production of clear treated water, methane, liquid affluent and fertilizers [Lettinga, Haandel 1993].

Costs: It requires a large land area, hence evaluation of land use may be required.

In this chapter, I have shown that based on the criteria of judgment, biomass technology actually offers an opportunity to Jamaica to use its biomass resources to generate energy instead of being the barrier. It simultaneously solves the problem of environmental pollution by eliminating sulfur emissions. If these technologies offer opportunities, then where are the barriers? Considering biomass resources and technology, how far is it feasible to produce energy from biomass by using BIG/ISTIG technology in Jamaica?

This question can be answered by actually simulating implementation of one project in Jamaica and testing its feasibility.

CHAPTER 5 THE PROPOSED ALTERNATIVE AND CRITICAL EVALUATION

In the previous chapter, I described the comparative advantage of biomass versus fossil fuel and that of power plant technology using biomass versus fossil fuel to generate electricity. I covered the advantages and disadvantages of the power plant in terms of capital cost and environmental emissions. I also described the advantages and disadvantages of gasoline versus biofuels.

In section A of this chapter I shall first propose a general model for replicability irrespective of specific context based on the technologies mentioned in chapter 4. I will then assess the possibility of introducing the general model of "biomass to energy conversion" at a specific location in Jamaica based on energy demand and existing transmission -distribution network. Then I will 1) assess its fuel requirement, 2) outline its choice of fuel, 3) analyze fuel supply logistics 4) assess its outputs for environmental acceptability and deduce certain characteristics of the project. 5) show the revenue generated from this project, capital required for this project. 6) show approximately how much of the capital investment and technical capacity can be obtained locally for the implementation of the project. 7) show the source of revenue and destination of this revenue to show distributive benefits that may incur if such project is implemented in Jamaica.

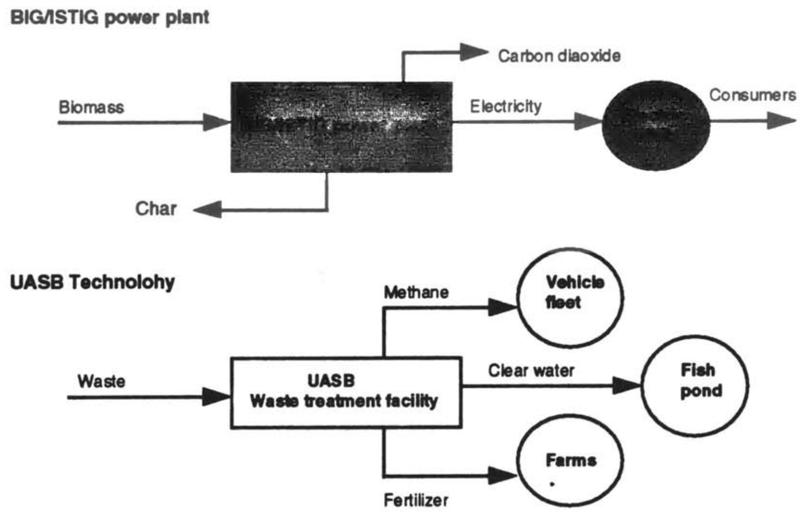
In section B I will evaluate the proposed alternative, details of which I will outline in the beginning of that section. Finally, from the evaluation I will draw lessons for replicability, to carry out other such projects in Jamaica till entire or at least half of its present installed capacity (495 MW) is covered.

Section A THE PROPOSED ALTERNATIVE

5.1 The general model

On next page I have shown a general model showing input and output for BIG/ISTIG power plant and UASB technology irrespective of which country context it is applied. However the feasibility of the energy project would best be tested at a specific location. In case of Jamaica where there is maximum energy demand, which happens to be at the urban center of Kingston. Other places such as Montego bay and Morant point with lesser energy demand may require smaller plants. At this point we do not know whether biomass or wastes are available near the point of highest demand and the location of the project.

GENERAL MODEL



Source: BIG/ISTIG power plant (Wiliams R., Larson G.1993)
UASB technology (Lettinga G., Haandel A.C.V.1993)

5.2 Example of prototype plant at Kingston

The urban center of Kingston has an energy demand of 190 MW as per the analysis of existing transmission and distribution network [ESSJ 1991](TPP93 report)(Map 1). The biggest feasible BIG / ISTIG plant available is of 111.2 MW capacity, hence Kingston would require an additional plant 79 MW capacity to satisfy the balance demand of 190 MW - 111 MW = 79 MW. However, considering the anticipated future demand, another plant of the same capacity (111.2 MW) would be preferable. I shall analyze here the possibility of one BIG/ISTIG plant at Kingston.

5.3 Fuel requirement

Installing BIG/ISTIG of 112.2 MW (in power mode) or 97.4 MW (in cogeneration mode) plant at Kingston will require biomass fuel at the rate of 57.7 tons/per hour or 5054452 tons/year [Ogden J., Fulmer M. April 1990].

5.4 Criteria for fuel selection

In the Jamaican context, the fuel selected must satisfy three essential criteria: First, its supply must be relatively assured for thirty years (the economic life of the power plant) so as to amortize the loans and investments. Second, it must be available year round and regularly. Third, it must be easily accessible and physically located around an established transport network so that it can be easily supplied. Which biomass and waste will the BIG/ISTIG plant use as fuel? This may require an assessment of various fuel sources.

5.5 Choice of fuel

Among the many biomass resources around Kingston, the largest biomass resource is the forest, followed by sugarcane, banana and the wastes (see table 2).

There are two ways in which biomass from forest could be used, either as a whole tree chipping or as the forest residues. Whole tree burning concept can be applied if the trees are grown on a sustainable basis.

There are problems in using either forest tree chipping or residues. First, they are dispersed in the blue mountains at various altitudes with little transportation network, hence collecting and transporting biomass may be difficult, chaotic and dangerous during the rainy season. The second problem with the forest residue is that in the absence of any defined property rights, more forest may be harvested by self-proclaimed suppliers than needed by the plant. This will lead to deforestation, hence its use is not desirable. If the current trend of deforestation and expansion for settlement continues, probably there may be less area covered by forest, making fuel supply unreliable.

The problem with banana and other crop residues is that their plantations are away from Kingston area, and distance determines the cost of fuel. Banana export was 75290 tons in 1991[ESSJ 1991] and residue from banana cannot be 505452 tons required by the BIG/ISTIG plant. Residue from a mix of all crops may be less preferable than a steady supply of predictable homogenous biomass. Banana can be considered among crop mixes only after other choices are ruled out.

The problem with waste is that there is no established sewage or waste collection system for Kingston and its surroundings (Interview -12). Waste is more suitable for UASB technology than for BIG/ISTIG. Hence it should not be considered.

This leaves the well established biomass "sugarcane barbojo"[13] (off season) and the "bagasse"[14] (during milling season) as the remaining choice.

5.6 Sugarcane bagasse and barbojo as fuel

Sugarcane is widely grown around Kingston on 82100 acres (see table 3) which can produce 2426857 tons[15] of sugarcane. During the off season it can produce a sugarcane residue "barbojo" of 800862 tons at the rate of 330 kg/tc[16] (based on the recovery rate of 80% [Williams, Larson 1993]) and a milling cycle of 133 days a year [Ogden J., Williams R., Fulmer M. 1991]. Hence it is available for 232 days a year. The next question is how its supply can be assured ?

5.7 Inducing supply of barbojo through incentive

The supply of barbojo can be induced from plantations and farms for 232 days as it generates additional revenue to plantation owners and farmers which they would not have received otherwise, since they burn the barbojo [Williams, Larson 1993][Goldemberg, Monaco 1993][Ogden, Fulmer 1990]. Hence the supply of barbojo can be available for 232 days in the year during the off season. But what about the remaning 133 days during the milling and harvesting season ?

5.8 Inducing bagasse supply

After obtaining barbojo for 232 as shown in 5.7, for the remainder of the 133 days during growing or harvesting season, biomass fuel can be obtained in the form of bagasse from either sugar factory or distillery. Bagasse supply can be induced from the distillery or sugar factory as it generates an additional revenue to them. Typically bagasse is used to generate electricity by sugar factory or distillery so that all of the bagasse can be burned off. This is because the left over bagasse would become a pollutant, and cost extra for its disposal [Ogden, Williams, Fulmer 1993]. But the use of all the bagasse to generate the small amount of electricity required for onsite needs, results in lower energy efficiency as the bagasse has a higher energy potential than the electricity produced from it.

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13 Barbojo is a latin word for tops and leaves of the sugarcane plant.
14 Bagasse is the residue of sugarcane plant after the sugarcane juice is extracted.
15 Based on 1991 productivity of cane per acre [9].
16 tc = tone of cane.

5.9 Location criteria and location in Kingston

Where can such a plant be located in Kingston ? What needs to be considered is it's requirement of obtaining barbojo from sugarcane plantation and bagasse sugar factory or distillery. Locating the plant in the proximity of these units can save transportation costs of each material flowing between them. There are three sugar factories in the vicinity of Kingston, one of them being the Bernard Lodge and one distillery "Petronol". As the Bernard Lodge sugar factory and the Petronol distillery already exist, locating the remaining BIG/ISTIG plant next to it may be preferable (map 2).

5.10 Integration as the approach of implementation

The approach that I adopted was to chart a material flow using input/output table as shown in (table 4). Then I selected technologies so that outputs from various units were utilized till they produce environmentally and economically acceptable and useful commodities (see table 4). All units can then function as an integrated bioresource energy project,

5.11 Material flow, the need for UASB technology and quantitative derivation

The material flow in such an arrangement is as shown in the diagram 1 on page 30 and quantitative derivation of materials are shown in (table 5) The problem of stillage from the distillery as an output would require a waste treatment facility. UASB technology can be introduced as shown in the same diagram 1. In the diagram 1, existing units are 1) sugarcane farms or plantations 2) sugar factory 3) Petronol distillery 4) Petrojam dehydration facility 4) EEC import 5) export to USGC - USA and the proposed units are 1) BIG/ISTIG power plant 2) UASB unit.

In the diagram 1, the wet ethanol from EEC is the only import, but I have shown that alternatively wet ethanol can be obtained from Petronol distillery hence EEC wet ethanol would not be required. Hence oil import is totally replaced by indigenous biomass as a fuel for power plant.

5.12 Resolving environmental problem of Kingston bay

If UASB unit acts as a joint waste treatment facility for the waste from the Kingston metropolitan area then it can resolve the problem of the waste going into the Kingston bay as Kingston doesnot have any waste treatment facility.

INTEGRATED BIOENERGY RESOURCE PROJECT

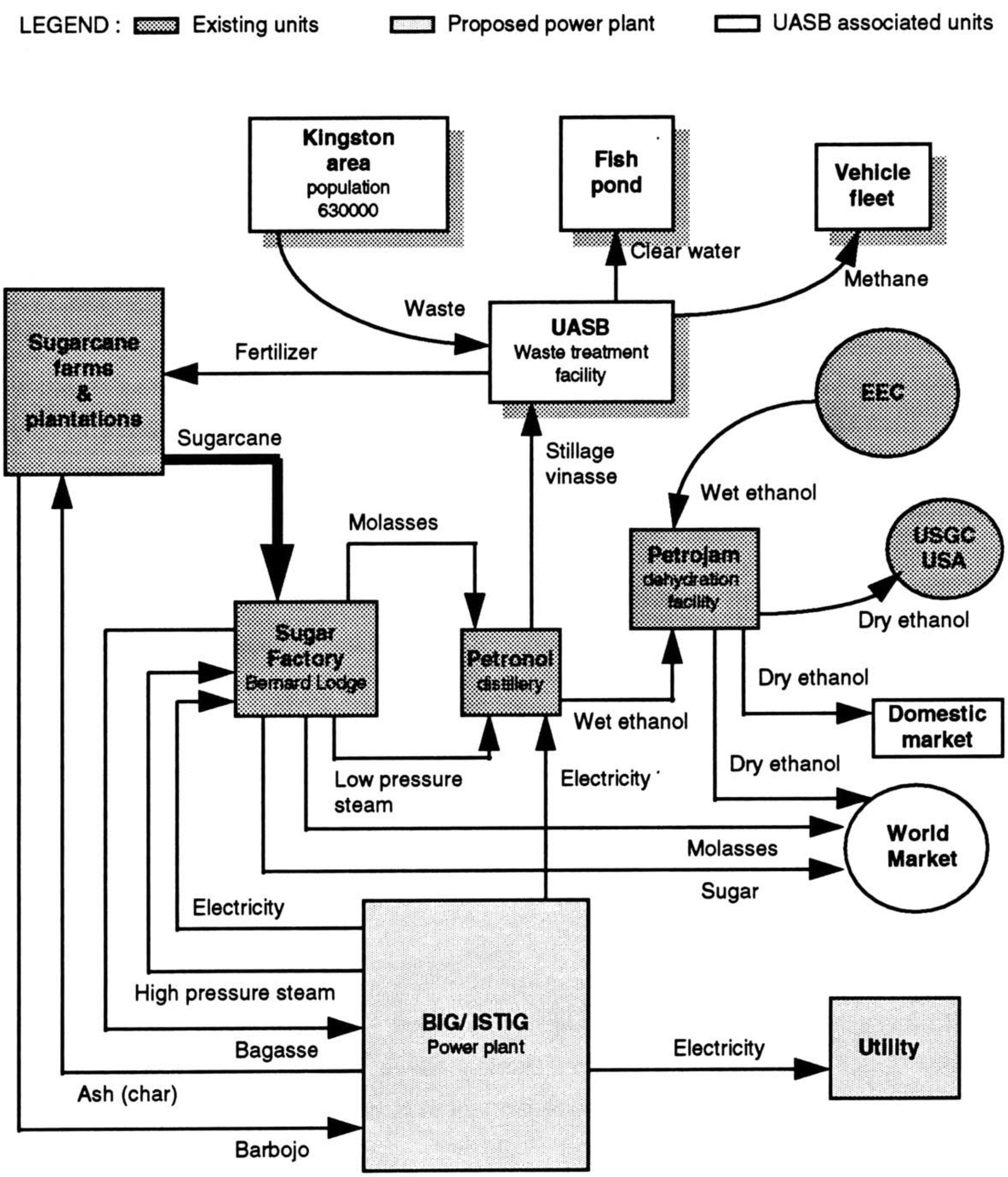

Diagram 1 **Source:** Arranged by author derived from (table 4)(Jinraj Joshipura 1993). Existing units based on field work. Arrangement and addition of BIG/ISTIG units based on learning about relationships from [Williams R, Larson E. 1993] [Ogden J., Fulmer M. April 1990] [Ogden J., Williams R., Fulmer M. 1990], arrangement and addition of UASB units based on learning from [Lettinga G., Haandel A. C. V. 1993]. Market units are added based on field work interviews and general information on sugar, molasses, ethanol.

Although, the above relationship seems workable, from my fieldwork based knowledge about Petronol, Petrojam and sugar industry in Jamaica I can foresee that the above project will face several constraints and barriers. In addition it derivation is based on several assumptions which can turn into barriers, which need to be examined before this project can be implemented.

Section B CRITICAL EVALUATION OF THE BIOMASS ALTERNATIVE

In this section, I will first identify a sequential constraint, then its effect on price of electricity and highlight the quality of integration necessary for the operation. Second, I will identify constraints and uncertainties in the supply of barbojo and bagasse which have to be dealt with as they are the fuel for the plant. Third, I will identify constraints in the operationality and success of the project such as cost benefit analysis, energy balance etc. for the viability of the project. Fourth, I will assess the effect of external influences on the project, which would need contingency planning. Fifth, I will identify two major assumptions.

In the end I will show that even if all other constraints are removed and the contingency planning is carried out, the "biggest constraint" will be the declining supply and the productivity of sugarcane which is caused by several reasons but chief among them is the attitude of labor. How does one resolve that ? I shall begin with sequential constraint.

5.13 Inevitable sequential constraint or "filters" in implementation:

To produce electricity from sugarcane residues, production of sugar, molasses, alcohol and the treatment of stillage are inevitable.

This is because this project has inevitable sequential constraints which have to be resolved at each stage of the material flow. For example, for this project to generate electricity using sugarcane residues as biomass at Kingston would require barbojo from sugarcane crop and bagasse from sugar factory or distillery.

However, their supply is not assured.

As per my methodology there are several filters which would prevent bagasse and barbojo from flowing smoothly as an input to the BIG/ISTIG power plant. This filters have to be identified.

For example, the distillery cannot supply bagasse unless it produces ethanol, and it will not produce ethanol unless it can sell ethanol and receive molasses or sugar cane juice, which are its raw materials. Sugar factory and distillery will not produce sugarcane juice or bagasse until they plan to produce sugarcane juice, sugar or ethanol. But the sugar factory will not produce sugar or sugarcane juice unless they can be sold. Under the present condition, a sugar factory can sell only a limited amount of sugarcane juice to Petronol distillery and a limited amount of sugar under the quota (see section 3.9). To produce and sell more sugar it has to reduce its production cost below the international market price. It can offset production cost partially by selling bagasse, and it can credit this additional revenue to the production cost of sugar by using it as a leverage. But it cannot sell all the bagasse till it reduces its steam demand and steam demand cannot be reduced until new steam saving technologies are introduced which will increase rate of sugar production and reduce its production cost. Selling part of the bagasse is not enough as a fuel to the BIG/ISTIG power plant.

But none of these units can produce anything until sugarcane is produced and it cannot be produced if the land for sugarcane is not available.

Even if the land is available, constancy in the productivity of sugarcane per acre needs to be maintained to ensure the supply of the required quantity of sugarcane for 15 years or 30 years (the economic life of the power plant BIG/ISTIG).

5.14 The factors affecting the price of electricity and its fuel:

From the above constraints it becomes clear that the price of electricity will depend on the price of fuel input - bagasse, which will depend on the average cost of either sugar, molasses or ethanol.

Reduced production of either sugar, molasses or ethanol will increase its production cost and it can only be offset by increasing the price of bagasse or barbojo, which in turn will effect the price of electricity, keeping all other variables constant.

Reverse of it - a higher production of any of the three (sugar, molasses or ethanol) will reduce their production cost and this means no need to charge higher price for bagasse, thus reducing the price of fuel, thereby decreasing the price of electricity.

Thus to produce electricity from sugarcane at a cheaper rate, not only the production but an increased production of all other products namely sugar, ethanol or molasses may be necessary.

5.15 Integration

It becomes clear from the above sequential constraints that functional, financial, and decision making integration will be the key to its implementation due to interdependency and complimentarity of units. This is the quality inevitably essential to maintain the input-output flow of material and energy.

Can it be achieved ? Will such a project succeed if installed ? If yes then what would it take to make it successful ? If it would not succeed then why would it not ? This requires a critical assessment of all contraints and "what if scenario".

5.16 Constraints, "what if scenarios" and contingency planning

It becomes clear from the above sequential constraints that simply locating the BIG/ISTIG plant next to a distillery, or a sugar factory, or a sugarcane plantation is not a sufficient condition for it to receive the supply of barbojo and bagasse.

The supply of fuel (barbojo and bagasse) has to be assured.

This supply can be interrupted under any of the "what if scenario" or due to various "constraints". This project must be planned for contingencies and kept prepared for any of the "what if scenario" prior to the installation of the BIG/ISTIG plant. Hence next I shall examine each of the constraints along with the "what if scenarios" associated with these constraints in detail and suggest possible contingency plans.

A) Fuel supply constraint: supply of bagasse

To obtain the supply of bagasse from the sugar factory or Petronol distillery, its milling section has to be kept operational. But the milling section cannot remain operational until either the sugar factory remains operational to produce sugar, or alternatively the distillery remains operational to produce ethanol. These are the primary products from which the sugar factory and distillery earn principal revenue, whereas bagasse is only a residue to these units. Hence market has to be assessed for the sale of these products. There exists an ample market for sugar, and this market is growing at the rate of 1.5% per year, hence there are no constraints from the market [The World Bank report 1992], but there are operational constraints which have to be dealt with.

To keep them operational all other obstacles and constraints (mentioned below) need to be removed.

A 1 Operational constraints:

What if scenario 1) But what if the Bernard Lodge sugar factory closes ? Then there will no suuply of bagasse.

This can very well happen and the sugar factory may close for three different reasons.

First, currently it makes a loss due to the fact that it has been assigned a fixed quota of production by Government of Jamaica which is less than its production capacity. This quota cannot be increased because this quota is based on the total quota allocated by US and EEC to the GOJ which is further subdivided among all the operational sugar factories causing losses. This trend has already set in and 7 out of 16 sugar factories in Jamaica have closed down over the years. None of them have been able to produce sugar at international market price, which is lower than the Jamaican production cost of sugar. The only way they export and earn foreign exchange is by selling under the average subsidized price of $393/ ton compared to the international market price of $266/ton.

Second, it can also close if these subsidized prices and the quota are removed. This is not scenario but a real possibility[17]. Although the exact quota allocation is not known, but as per such a scenario entire quota can be eliminated. Hence there will be no export of sugar, no sugarcane production and no production of bagasse or barbojo. In addition, it can create enormous unemployment in rural area affecting approximately 75000 people [ESSJ 1991]

Third, a UNDP report [13b] prepared and published in August 1992 assumed the closure of the Bernard Lodge sugar factory [page A-206, 8(b)], hence UNDP advise may be followed by Government of Jamaica.

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17 The Financial Times 8/15/93. " US sugar cut to cost Caribbean." New quota for the year 1993-94 for the region will be 225,508 tons with Dominican Republic supplying about three quarters.

However it was operational when I visited them in January 1993 and is operational today.

A contingency plan would require that the Bernard Lodge sugar factory be kept operational to produce sugar so that it can supply bagasse. To ensure that it remains operational would require that its losses are reduced. One way to do that is by increasing the production of sugar which would decrease its current production cost. The feasibility of higher production of sugar is based on the available market, which exists only if the sugar price that the sugar factory can offer to the market is competitive. Again, that depends on the production cost at which sugar is produced, which again depends on the efficiency of extraction and energy consumption. Hence from these constraints it is clear that the higher production or operational status of the sugar factory is not automatically assured.

In the absence of an assured operation of the sugar factory, a contingency plan would also require that the alternative of distilling sugarcane juice to produce ethanol be kept open, so that the milling section can remain operational to crush sugarcane to produce sugarcane juice for ethanol while supplying bagasse.

Again to keep the distillery operational and producing ethanol, it follows that the market for ethanol has to be assured which does exist at United States Gulf Coast. As per the UNDP report (B, page A -204), the current market for ethanol is 68 million usg and projected to expand up to 208 million in 2001. The current Jamaican capacity to produce dehydrated ethanol, after the 15 million wet ethanol of the Petronol is dehydrated by Petrojam, is only 13.5 million usg.

What if scenario 2) But what if the Petronol distillery is also closed down as per the advice of UNDP report ?

In such a case, there will be no source for the supply of bagasse, at least not at the economical rate. As a contingency measure bagasse can be obtained from other sugar factories but it will incur additional transportation cost. Such a closure will eliminate biofuel production and no stillage will be available for UASB units from the distillery.

There are two reasons for the losses and the probable closure of Petronol distillery. First, it does not receive molasses (which is a raw material to produce ethanol) from the sugar factory; instead, the molasses is sold off to rum factories by Petroleum Corporation of Jamaica which controls the sugar factory. Second, that Petrojam buys less wet ethanol from Petronol.

According to the Managing Director of Petronol, the decision to buy less wet ethanol from Petronol is based on the fact that the cost of ethanol from Petronol is higher than the imported wet ethanol from EEC; hence, molasses need not be given to Petronol as PCJ has no utility of Petronol. This fact of price difference has been mentioned in the UNDP report 135(B).

UNDP report 135(B) August 1992, did advise the government of Jamaica to close down the Petronol distillery [4.16, page A -212].

Why would the UNDP report give such a contradictory advice even after taking note of the larger market potential and why is it that Petronol cannot produce wet ethanol to its full capacity when such a market exists?

I examined the UNDP report 135(B) for two reasons. First, to find out why the cost of imported wet ethanol is considered lower than the locally produced wet ethanol (page A - 203). Second, to find what led to the conclusion in the UNDP report that Petronol is not profitable and should be closed down (4.16, page A -212).

I found that these two decisions were flawed since they were based on the wrong foreign exchange parameter used in the report. First, the production cost of wet ethanol from EEC, if calculated on the prevalent exchange rate of US $1 = JS $22, would be higher than Petronol. Second, the decision to advise the GOJ was based on a negative NPV in the worksheet.

I examined the worksheet in the UNDP 135(B) report by using my methodology of identifying translation mechanism and the translator (currency exchange rate). I found that this worksheet was also based on the wrong exchange rate parameter of US $1 = JS $8 when the rate was US $1 = JS $22 [page viii, 8(b)]. I recalculated the worksheet and found that at that rate NPV turned out to be positive (worksheet 2). Based on the rate of US $1 = JS $36[18], the cost of wet ethanol at 0.57c/usg from EEC [page A-203, 8(b)] is higher than the cost of wet ethanol from Petronol at 0.47c/usg, hence as per the configuration Q, (obtaining maximum ethanol from Petronol and the remaining from EEC) is a better strategy for Jamaica (see worksheet 2).

Explanation of worksheet 2 :

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18 Obtained from Baybank on 8/13/93.

This worksheet shows an economic analysis of choices that the Petrojam faces in selecting the source of wet ethanol. It has three choices 1) buy it's own from Petronol 2) Import it from EEC 3) import it from its own subsidiary in Belize. The last two incurs import and fobbing cost. The task is then to find which one of them is the cheapest source and present a positive NPV for the Petrojam and the Jamaica.

Section A shows the capacity of two units and yield, section B & C shows the production cost at different exchange rates of the two units which includes the rate UNDP report used, rate that was prevailing at that time and the current rate of J$36=$1. Section D shows investments including the waste treatment plant, the revenue from which was not added by UNDP report. Section F shows prices for 1. unleaded regular gasoline price in barrels and 2. for US gallons, also shows 3. gross subsidy and 5. net subsidy effect after deducting expenses, 8. Petrojam's net price.

This prices and revenues are applied to form 3 configurations and 8 alternatives. I have also shown that how ethanol can be used competitively for local gasohol program and as a neat fuel. The results are quite clear from this table that Petronol operations should not be closed down since they are profitable under old and new conditions.

Inference 1

The conclusion is that it is economically feasible to produce wet ethanol from Petronol distillery despite the UNDP recommendation. This will allow it to remain operational and supply bagasse to the BIG/ISTIG plant.

A 2 Technical constraint of bagasse supply:

The next question is, will it be technically feasible for the sugar factory or distillery to supply bagasse? There are technical constraints such as steam and electricity requirement of sugar factory and distillery for which contingency planning is required.

When energy efficiency is considered, a typical conventional sugar factory and distillery are highly inefficient. In fact they are designed to be inefficient [Williams, Larson 1993]. Sugar factory has an in-built electricity plant which is supposed to use all the bagasse it produces in such a way that it produces just enough steam and electricity for on-site needs only. Efficiency ratio or energy balance are not considered. This is because the purpose of such an energy unit is not to leave any bagasse which may create a disposal problem (pollution in the form of stillage).

Thus there is no bagasse left to be supplied to BIG/ISTIG plant unless the plant supplies steam and electricity in return for the supply of bagasse instead of simply providing funds for the bagasse it received.

Inference 2

The sugar factory or distillery can sell bagasse only if it receives steam and electricity it needs and can also receive additional revenue for the bagasse if it arranges with BIG/ISTIG. This way the bagasse can be utilized efficiently both in energy and economic terms.

A 3 Engineering constraint:

But the engineering constraint is that steam demand and use of conventional sugar factory and distillery at the Bernard lodge are higher[19] than the generation capacity[20] of BIG/ISTIG plant. So to receive steam and to supply bagasse, the sugar factory and distillery have to introduce new and efficient sugar and ethanol extraction technologies [Extraction de Smet 1988] such as those listed in table 5.15 which will reduce their steam demand to match steam generation of the BIG/ISTIG plant.

Depending on the detailed engineering analysis of the use of steam and electricity, savings from use of steam can go to the price of sugar or alcohol, making either one of them cheaper and profitable. In addition, a detailed cost accounting of both capital costs and the operational costs are necessary on an on-line basis. At the same time, depending upon the market price, the management can decide to credit either of the products to make them cheaper irrespective of which one uses more steam so that both can be sold. This is essential as their production process overlaps. This would make more production of sugar feasible while assuring availability of bagasse. This was anyway the goal.

Inference 3

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19 464 kg/tc medium pressure steam at 2.1 MPa, at 300 degree centigrade temparature [Ogden, Fulmer 1990].

20 235 kg/tc [Ogden, Fulmer 1990].

Hence, the conclusion is that if technical improvements are carried out, it is both economically and technically feasible to keep the sugar factory and Petronol operational so that bagasse can be supplied to the BIG/ISTIG plant. In addition, by increasing production and decreasing energy use, its production cost can be reduced which will enable it to compete at the world market.

Table 5.15

	Process	Measures required	Steam savings (kg/tc)	Other factors	Status
1	**Cane milling**				
a)	steam driven mills				in use
b)	electric mills	Use of electric motors to drive the mills	200 -250	Double transformation of energy	in use
c)	diffusers		200-250	The diffuser process can run on electricity	in use
2	**Juice heating**	use hot condensates	5-10%		
3	**Evaporation**	Use falling film evaporators	30%-45%	No problem of color formation	in use in Jamaica
		Use Mechanical vapor recompression	100%	Electricity is substituted for steam	in use
4	**Vacuum pans**	Use of continuous vacuum pans	25% less		experimental stage
		Use of multiple effect pans			experimental stage
		Mechanical vapor recompression		Power consumption can be high	experimental stage
5	**Fermentation technologies**	Described in the separate table			
6	**Distillation**	Solvent extraction	100%		Commercial
	Ethanol separation	Solvent extraction	100%		Commercial

Source: Rearranged by author from the work of Ogden J., Fulmer M. April 1990.

A 4 Policy constraint:

What if scenario (3) What if the Government of Jamaica, as advised by UNDP succeeds in selling off the Bernard Lodge complex sugar factory, distillery and sugar plantation (advertised- 8/1/93 The London Times)?

This decision may be again based on UNDP report which might have convinced GOJ to follow privatization and decentralization path as advised by the World Bank. There are several possible scenarios which emerge out of it.

First, the new investor may decide to invest in the BIG/ISTIG plant. Second, the investor may decide to invest only in refurbishing sugar factory, distillery and in operating and selling bagasse. Third, the investor may decide to strip it off of all its assets and further sell it as separate unit to new investors.

What if scenario (4) What if the new investors are not willing to supply bagasse or barbojo, or demand higher price than the cogeneration plant can afford to pay ?

Either of these possibilities make the supply of bagasse difficult. Obtaining supply of bagasse can become even more difficult if the sugar factory, distillery, dehydartion facility and sugarcane farms were sold separately to different owners.

This is because such a privatization can create a number of conflicting situations. The sugar factory owner might want to strip off the assets, sell all the machinery and steel as a scrap for quick profit. Such a decision may depend on what price he or she paid in auction. The distillery owner might want to brew rum instead of ethanol, which is fair. And in the absence of any environmental laws or enforcement, investors may not like to invest in a waste treatment facility. This may result in the continued pollution flowing into the Kingston Bay.

Even if we assume that all investors decide jointly to invest in BIG/ISTIG plant, there still may be conflict over how much price should be paid by or received by the plant for bagasse, barbojo, sugarcane or stillage. Each of the owners may demand more price for their items even if it means a loss to the power plant.

Even if the price of their individual items are agreed upon, the different styles and pace of management in day to day operation of each of the supplying units might create delay in the supply of individual items to the power plant.

Inference 4

a) Privatization of individual units in these case may not be beneficial if the goal is to create integrated bioenergy resource project.
b) Integration of ownership may be a better approach.
c) It also raises the question as to whether privatization of energy should be followed blindly from utility to the supply of fuel ?

B) Fuel supply constraint: supply of barbojo

The supply of barbojo can be delayed or interrupted by several constraints:

B 1 Productivity constraints based on burning of Barbojo: Barbojo is burnt in all countries including US. preharvest (dry leaves) burning is done to promote pest control and to lower harvest costs. Post harvest burning is done to eliminate trashy residues and so expedites plowing and replanting. However due to air pollution concerns, cane burning near urban area is undesirable (Goldemberg, Monaco, Macedo 1993).

B 2 Price constraints: Price dispute It can also be interrupted by a price dispute between the power plant on one side and farmers and plantation owners on the other side.

B 3 Transportation constraint: Transportation problems such as vehicle breakdowns and repairs would require a contingency planning including designing and implementing good transportation means.

Inference 5

It is assumed here that simply enacting a law banning cane burning may or may not be complied. However if cane burning fetches additional revenue then chances of cane burning are less because it is as good as burning dollar bills and such a behavior may not be expected from either poor farmers or rich plantation owners.

B 4 Productivity constraint based on harvesting: Even if the supply remains constant, the productivity of barbojo can vary. This is because, as the drawing in appendix shows, what constitutes sugarcane stem used for sugarcane juice and the residue of the stem, varies from plant to plant. In addition, the precision with which it is cut varies from worker to worker, and hence the productivity of barbojo can vary per acre or per ton of cane.

Contingency planning for overcoming the problem of productivity of barbojo would include (1) making molds for cutting cane so that cane stems are more uniform (2) eventual mechanization of harvesting and processing, (3) fixing supply terms in such a way that every supplier has to supply the agreed quantity of barbojo. If the agreed quantity is supplied then the supplier gets a bonus at the end of contract. However this type of contractual condition can lead to the possibility of more stem being supplied. This may cause problems as the barbojo would have a greater proportion of the stem with a higher moisture content. Moisture content higher than 15% may not be acceptable to BIG/ISTIG plant [Ogden J., Fulmer M. 1990]. However, this is unlikely to happen as sugarcane stem fetches higher price than its residue, hence, farmers are not likely to supply more of stem.

Inference 6

It is predicted here that the specification associated with a financial incentive would assure the supply of barbojo of desired quantity and quality

C) Constraint and "what if scenario" in the supply of sugarcane

There are many possibilities of sugarcane supply interruptions.

C 1 Opportunity constraint

What if scenario (5) What if the sugarcane farmers stop sugarcane production in favor of other crops for higher profits?

Farmers may not shift to a new crop since they earn revenue not only from the crop (sugarcane), but also from its residue "barbojo", and no other agricultural crop has such a dual value. In addition no other crop has such a high demand in terms of quantity.

C 2 Climatic constraints

What if scenario (6) What if the "hurricane" or "drought" destroy or reduce the sugarcane crop? [ESSJ 1991]?

A. This possibility is real, severe hurricane can reduce if not destroy the entire sugarcane crop. That will leave the whole crop on ground, along with the stem, leaves and tops.

When dried in the sun, they still have photosynthetically captured energy for gasification and electricity generation. In addition it still leaves the possibility of producing ethanol from the urban stillage and other crop residues. Hence an alternative proposal of multi-crop distillation process is extremely useful. Multi-crop distillation also allows for other crops namely sorghum, potatoes and cassava to be grown during the rest of the 232 days as part of the plant rotation. They can be used to produce ethanol from the same distillery with some technical improvements.

B. The second possibilities is that of " drought ". However, this is unlikely in the tropics. "Drought" will make ample biomass available, which if not used would burn on its own. If it is not collected and used, then it may burn as bush fires (which occur frequently in California).

At such a time of crisis, government's reserve funds can be utilized to collect biomass. This will create rural employment for the unemployed farm labor. This is a very useful and timely public policy action, when in the absence of rain and crop failure, farm income might have declined.

The question then is how to use all the biomass or store it safely ? This opens up a question for research. One possibility is that gasified biomass can be stored in the from of gas to be used for driving gas turbines later. Such a disaster also calls for the need of small hydro dams spread over the country, for which Jamaica has a suitable topography. Irrigation can be carried out to save the crop in "drought". However dams need not be large enough for hydro power because in such a case there is ample biomass for gasification and electricity generation.

Inference 7

Considering scenario 5 and 6, I infer that farmers may not shift to different crops due to added value offered by residue and "Drought" or "hurricane" may be critically harmful to sugar factory but may not prevent the operation of the BIG/ISTIG power plant.

D) Constraints in the success of the bioenergy resource project

D 1 Environmental constraint (assessment and contingency plan)

A waste treatment facility would be a necessity for the treatment of stillage (waste water-vinasse) from the distillery. While the UNDP report considers it a necessity, it also considers it a problem because it entails an investment which increases the production cost of ethanol. However this is not true; as I have shown in worksheet 2 (configuration 1 alternative 3), even with such an investment, NPV can be positive. In addition, I have show that waste treatment facility also offers an opportunity to improve energy and economic ratios for the entire project (see tables 6 and 7).

A waste treatment facility is based on a high rate anaerobic digestion system to treat various wastes arising from sugarcane factory, distillery, cogeneration plant. Waste water has 12% energy content of cane and can cause pollution if allowed to drain in water ways without appropriate extraction and treatment. Complex organic compounds transformed during this process, result in mainly methane (including other stable gases) and carbon dioxide. Methane is a form of energy. This facility may occupy at 5% of cultivated land when "evaporation lagoons" are used [Lettinga G,. Haandel A. C. V. 1993].

To improve energy economic balance further, this treatment unit can also serve a surrounding Kingston metropolitan area of 600,000 people in treating its wastes. This would add revenue to the whole project as it can charge the city for the treatment of sludge, and in addition earn revenue by selling its byproducts.

Inference 8

The contingency plan would require attention on key elements of such solutions: (1) request CIDA[21] to provide different type of assistance so that fertilizer from UASB unit can be sold; (2) give tax reduction to those trucks which will use methane instead of diesel; (3) all diesel not used by those trucks that use methane can be exported by the refinery; (4) develop clear water fish pond for fresh water fish.

What if scenario (7) What if CIDA stops exporting fertilizer ?

Sugarcane farmers in the vicinity of Petronol do not buy treated stillage (fertilizer) from Petronol even though it is being sold at a cheap rate [interview A-6]. I later discovered that price of fertilizer sold by CIDA was cheaper than Petronol [interviews A-7]. But as I have shown above that even if CIDA stops fertilizer, that will help the project by increasing the demand of the fertilizer.

Inference 9

Hence it is clear that even wastes in Jamaica in its present context offer potential for energy and contribute in energy savings by replacing an import component (see table 7 for the value of savings).

In addition, it may be a lesson for International aid agency that if a country can help itself why not allow it so that the tax payers of the donor country do not suffer.

21 Canadian Industrial Development Agency

D 2 Economic constraint

What if scenario (8) What if the economic output/input ratio is lower when discounted then this project may not be viable?

Economics of the cogeneration BIG/ISTIG plant:

Examination of the worksheets 3A, 3B, 3C shows that the net present benefits at market prices are positive so that this activity can sustain itself without any external protection or subsidy. I have shown this in the worksheet 3A as commercial appraisal using shadow price (market price) of $266/ton instead of $604/ton or $407/ton for sugar. For ethanol I have used $0.42/usg (considering oil priced at $15/barrel) instead of $0.90/usg for ethanol. This takes care of the argument for the continued current price of crude oil. There are no subsidized prices for other products. In section C of this worksheet I have calculated revenue from electricity at four different prices (2,3,4,5 cents/kWh) in order to compare it with the cost of electricity generated with other energy resources. I have also calculated their respective NPV at four different discount rates in sections G, I, K, M. I have shown social benefits in the worksheet 3 C.

Various sectors of economy in terms of levels and geographical regions will benefit from this project. Possible combinations of income distribution for several sectors from its sales and exports will stimulate the local economy. Different groups will receive different revenues for the products they will produce. Table 5 shows who will receive how much at the Bernard Lodge project involving cogeneration plant, sugar factory, distillery, and the waste treatment facility.

Inference 10

It is economically feasible to operate a BIG/ISTIG plant in Jamaica based on the data and assumptions.

D 3 Energy efficiency and energy balance constraint

What if scenario (9) What if the energy output/input ratio is negative from biomass to energy services, then the project may not be considered viable in terms of energy efficiency?

Inference 11

This project either as an integrated or as a separate unit has positive energy input/output ratio (see table 6)

D 4 External subsidy constraint

What if Scenario (10) What if EEC decides to cut off the supply of wet ethanol ?

A possibility of wet ethanol supply cut off from EEC may hurt Jamaica's export of dry ethanol to USA. This is because, although I mentioned earlier that importing wet ethanol is more expensive than to obtain it locally (section 5.16, A 1, under what if scenario 2 in paragraph 7, 8, 9), Jamaica still needs to import wet ethanol. This is because capacity of Jamaica to produce wet ethanol is only 15 million usg whereas its capacity to dehydrate is 50 million usg.

This is very likely because EEC buys wet ethanol from its Farmers under the scheme known as " wine lake" . EEC pays $6 per usg and sells to other countries for $0.35 per usg thus makes loss or call it provides subsidy both to EEC farmers and buyer such as Jamaica at the expense of other citizens. I do not see how long EEC can continue to do and how much Jamaica should rely on such a supply at a negligible prices.

Inference 12

Hence the cut off of the EEC wet ethanol on one hand leads to a shortfall which can close Petrojam and Petronol but it may provide an incentive to Jamaica to source wet ethanol locally by building more distilleries. In addition the EEC citizens will benefit if such a subsidy is stopped. Environmentally EEC will be forced to treat this wine not good for human consumption Within EEC boundary which will provide jobs to EEC citizens.

D 5 Demand Constraint

What if scenario (11) What if ethanol demand is eliminated in favor of electric cars ?

Even if the demand for fuel grade ethanol destined for USGC market becomes zero, demand for industrial alcohol is ample. Alternatively sugar factories can export molasses instead of using it to produce wet ethanol which has ample demand [Molasses and industrial alcohol].

The other possibility is that the demand for ethanol may rise, not for it's direct use, but as a raw material to a superior additive to gasoline ethyltertiarybutylether (ETBE). As per UNDP report ETBE has superior blending properties to methyltertiarybutylether (MTBE) produced from methanol.

Inference 13

Thus the demise of demand of ethanol for automotive use has no effect on this project

5.17 Contingency planning against external influences on the project

A 1. Competitive constraints:

It was stated earlier that a TPP93 report concluded that biomass has the highest energy potential with a specific reference to Jamaica.

What if scenario (12) What if all other NRSE resources namely solar, wind, hydro, DSM and biomass have equal energy potential; how and why would the use of biomass be justified?

Refer to table 8 for a comparison of various operational problems that arise in the implementation and success in the use of different NRSE.

Inference 14

Biomass as an energy resource has the least amount of operational problem when compared with other NRSE.

A 2 Replicability constraints

What if scenario (13) What if this type of project cannot be replicated ?

This constraint is real in the sense that this project cannot be replicated in exact form but with a variation of the same arrangement. Reasons for variation are that (1) other sugar factory and distillery are privately owned hence their relationship with Petrojam will differ. (2) even if the other units are owned by Government of Jamaica, they are away from Petrojam. (3) sugar factory does not always have a distillery attached to it; there are independent sugar factories and autonomous distilleries compared to an annexed distillery at the Bernard Lodge at Kingston.

Inference 15

The coordination of other such projects has to be worked out on a case by case basis. For example, near Kingston another plant can easily be implemented as table 5 shows, as out of 82100 acres available near Kingston only 36975 acres are required by one BIG/ISTIG plant. Hence the balance of 45125 acres of sugarcane land is available for one more BIG/ISTIG power plant to satisfy 79 MW of balance of demand.

A 3. Assessing distributive effects

The question in this section is, are there any distributive effects which would not help Jamaica? For example is there any import of energy required for the operation of the project ? Table 5 shows the calculations of the required barbojo, bagasse, sugarcane land, sugarcane juice, and products that can be produced such as sugar, molasses, and ethanol. It also shows the origin and destination of the revenue by classifying them into paying sectors and receiving sectors. It clearly shows presence of exports of commodities such as sugar, molasses and ethanol but absence of import. Table 7 shows all the commodities produced which also include electricity, methane, and stillage from such projects and their respective revenue.

Inference 16

From the above tables it becomes clear that there is no payment for the import that leaves the country during the thirty years of operation of the BIG/ISTIG plant except the payment of capital cost of power plant, its interest and funds for spare parts for the plant.

The benefits in terms of export revenue enter Jamaica. In addition, saved import payment for oil can also be considered export earnings which otherwise would have left Jamaica to pay for oil. Inside Jamaica, farmers and plantation owners receive additional revenue for the cane residues "barbojo".

5.18 Major constraints: Production of sugarcane

So far, I dealt with all the issues that affected the supply of sugarcane, its residues and the project as a whole including its replicability in Jamaica, while assuming that sugarcane will be produced in Jamaica.

There is no assurance that sugarcane will be produced.

To ensure that sugarcane is produced three essential elements have to be in place, namely rain to provide water, land to cultivate sugarcane, and labor to cultivate it. Among these three, only land allocation can be assured by the state. Rain cannot be assured but it can be presumed that as a tropical island, Jamaica will have adequate rain fall. However rains can be discouraged by land use resulting into deforestation. Labor cooperation can be forced but cannot be assured, however it can be coerced. I shall consider all three of them as constraints in the production of sugarcane and examine them.

A. Land use constraint.

Although the land allocation and land use is determined by acquiring and releasing of land by state, sometimes market forces and social agenda guide the decision of state. This is happening in Jamaica around Kingston.

What if scenario (10) What if land used for sugarcane crop continues to be allocated for other uses as is happening ?

This scenario raises question as to why the land slated and historically used for sugarcane crop would be allocated to other uses? Does it mean that the other uses for which land is allocated are more important to Jamaica than growing sugarcane?

Sugarcane land belonging to the Bernard Lodge factory has been allocated to the housing authority to provide prefabricated housing to unemployed poor people in the downtown Kingston. The housing has been built and was being built when I visited Jamaica.

Inference 17

I would compare and evaluate the decision to use sugarcane land for housing separately in the next chapter by challenging the conventional measure of land value. Here I would say that if land continues to be allocated, then from the view point of the BIG/ISTIG power plant the project will not get sugarcane residues as there is no land to grow it.

B. Constraints of water availability and the rainfall

As such this is not a constraint but it can become a constraint over the 30 years of the BIG/ISTIG plant life. For example, extensive deforestation can be caused by firewood and increased wood logging. The deforestation and land use may affect the rain pattern and irrigation and affect the productivity of sugarcane.

Inference 18

Addressing deforestation is an indirect fallout of this project. This is because one of the benefits of this project is that by reducing the price of electricity, this project makes electricity affordable to low income consumers. In addition, it would create jobs, make exports competitive and address general economic development if repeated throughout Jamaica. In such a situation even rural people would prefer and would be able to afford appliances which can use other forms of energy such as electricity, rather than using a direct smoke producing firewood.

5.16 Main constraints - assumptions and barriers

However it has been assumed so far that: (A) BIG/ISTIG technology and its spare parts will be available (political and technological barrier). (B) Sugarcane will always be grown in Jamaica providing barbojo and bagasse (supply barrier).

These assumption may not hold. hence I shall examine each of these assumptions and barriers.

Assumption A. BIG/ISTIG technology and its spare parts will be available - Political and technological barrier.

The manufacturer (The General Electric Company) is interested in the commercialization of such plants. An article in Boston Globe on 19th August stated that the company has announced plans to lay off workers at its aircraft engine manufacturing division because of declining orders by the aircraft industry. This means that there exists a surplus industrial capacity to manufacture these units. In Jamaica alone it could potetially sell BIG/ISTIG plants worth US $575 million. There are other manufacturers who could manufacture such plants besides The General Electric, but the irony is that there is no encouragement from the US government and the multilateral international agencies.

Inference 19

Hence it can be assumed that if market for BIG/ISTIG technology is identified, analyzed and justified by a feasibility analysis like this, the manufacturer will be willing to sell and the technology will be available.

Assumption B. Sugarcane will always be grown in Jamaica providing barbojo and bagasse (supply barrier).

This assumption that sugarcane will always be grown in Jamaica in desired quantity may not hold, if one examines the history of sugarcane industry from it's inception in 1510 to 1992.

B 1 History of sugarcane

Historically, sugarcane was introduced in Jamaica in 1510. Since 1929, Jamaican sugarcane industries has been given different forms of subsidies by the British, Jamaican and US governments for different reasons under different political and economic context. As per record, sugarcane production was 14,572 tons in 1699. It reached a·peak of 500,000 tons in 1970 and since then, it has experienced a decline (237342 tons in 1991 and further decline in 1992) both in sugarcane productivity per acre of land and in the production of sugar per ton of cane.

Sugar industry had to face a situation of crop failure at least once. Attempts were then made to grow sorghum. Experiments to grow sorghum (different variety of cane) carried out by Petronol research staff and the Ministry of Agriculture on sugarcane plantations belonging to the Government of Jamaica was not been successful. Yields from the farms were not satisfactory. It failed because of lack of interest of sugar industry, Ministry of Agricultural staff and farmers, to any kind of change [interview A-4, A-5]. The yield from sugarcane also has not been satisfactory when compared to the world productivity. When sugarcane sector was freed from subsidy and quota for a short time, it failed under competition and Government had to intervene and nationalize it again. [National Atlas of Jamaica].

B 2 Official reasons for decline

As per official documents reasons for this type of decline in sugarcane industry are as follows: First, the world market price is volatile. Second, the weather conditions are not favorable, hurricanes in Jamaica affect sugarcane crops. Third, there are technical reasons such as (1) low sucrose content, (2) stale cane delivery, (3) unreliable transport, (4) high proportion of extraneous matter, and (5) low efficiency in extraction in sugar mills [National Atlas].

B 3 Other reasons for decline

As per my interviews (A-3,4,5,6,9,B-2,3,4) during my field work in Jamaica I learned that in general, workers receive good salaries, housing and assured field benefits making them resistant to any change. They are shielded by the subsidized prices and high revenues.

They resist mechanization, modernization, improvement or introduction of new techniques which would threaten their ways of working and living. This led to the formation of various unions since 1929.

B 4 Prodcution of sugarcane " the biggest constraint"

Hence the biggest constraint is that of sugarcane production. This is reflected in the varying sugar production which was 14572 tons in 1699; reached a peak of 500,000 tons in 1970 and declined to 237342 tons in 1991. This is then a classical problem which Jamaica has been grappling with since 1510.

It has been declining due to many reasons, but chief among them is the lethargic attitudes of farmers and workers which is reflected by the varying productivity of cane per acre over the years.

Historically they hate the crop and call it a "whitemen's crop".

This is because, as the descendants of African slave labor which were brought to work on plantations, sugar has never been part of their diet and hence they feel that all the hard work they do in producing "sugarcane and sugar" actually goes in feeding the "whitemen".

Despite all these problems, the sugarcane sector is being kept alive under transitory protection and subsidies from EEC, US and GOJ while workers and farmers continue to resist any change which can improve costs and outputs by introduction of new technologies.

5.19 Principal question ?

Can an introduction of an even more advanced technology such as BIG/ISTIG - LM-8000 by General Electric Co., using advances in aircraft jet engines, biotechnology and bio-process engineering change their attitude ?

"Inference 20" - the key

It may, if they see that all the hard work they do in producing sugarcane not only produces "sugar" for the "whitemen" but also produces electricity, fertilizer, ethanol and methane, from the waste of their towns for their benefits.

Hence attitudes, perception, and lethargy are inversely proportional to the level of advancement in technology which can offer benefits not otherwise perceived through social engineering but may instead require engineering the "sociology" .

This may require filling in the future I/O tables with costs and benefits accessible through technological perception and not through normal human perception.

Summary: In this chapter first I proposed an alternative to test the feasibility of one biomass power plant in Jamaica, then analyzed all aspects of its feasibility including energy and economic ratios. Then, I identified several constraints, what if scenarios and the contingency planning required for it. In the end, I showed that technology can act as catalyst in improving a productivity.

Hence after evaluating the feasibility of a prototype BIG/ISTIG power plant I conclude that it is feasible to produce electricity at Kingston from biomass resources, namely sugarcane residues.

CHAPTER 6 CONCLUSIONS AND RECOMMENDATIONS

To summarize, in the preceding chapters I described an energy dilemma, and then redefined it as a multidimensional dilemma involving energy, economic and environmental issues which many developing countries face. Then I chose a case study of Jamaica which best exemplified this dilemma. Then articulated the dilemma with reference to Jamaica and proposed one prototype alternative using advance technology and indigenous resource to resolve the dilemma. Then I evaluated the proposed alternative from different perspectives which included constraints, what if scenarios and inferences.

In this chapter I will synthesize all the findings from literature, fieldwork and inferences to draw conclusions. Then I shall show that if such a prototype project is replicated in Jamaica based on the existing demand, transmission and distribution network, they can replace most of the installed generating capacity so that oil import becomes almost negligible. In addition I will show that replicating such integrated projects will create economic and environmental benefits beyond energy generation. In the end I will also propose recommendations specifically for the Jamaica and for general replicability value for over 80 countries of the world.

6.1 Summary and synthesis of inferences to draw conclusion

From analysis and inferences of the previous chapter it is clear that it is feasible to produce electricity in Jamaica from biomass by installing a BIG/ISTIG power plant and sell electricity at a cost less than a conventional or coal fired power plant. It is also economically feasible to operate the BIG/ISTIG plant in Jamaica based on the data and assumptions. This is feasible by obtaining bagasse from the sugar factories and distillery by keeping them operational despite the advice of UNDP and the World Bank Report. This integrated bioresource energy project either as an integrated or as a separate unit has a positive energy input/output ratio (table 8). Arrangement of other such projects in Jamaica has to be worked out on a case by case basis. For example, near Kingston another plant can easily be implemented because out of 82100 acres available near Kingston only 36975 acres are required by one BIG/ISTIG plant (tables 3,5). Hence the balance of 45125 acres of sugarcane land remain available for one more BIG/ISTIG power plant to satisfy more than the balance of 79 MW of demand.

To keep sugar factory and distillery operational for bagasse, it is necessary to keep them viable. To keep them viable it is technically and economically feasible to reduce production cost of sugar by introducing new technologies which would improve the extraction rate and energy consumption. Reduced production cost of sugar would make it competitive on the world market and allow the sugar factories to operate at their full production capacity and stop making losses. In addition if more BIG/ISTIG plants are introduced, there would be enough demand for bagasse and barbojo, thus making it feasible to restart those sugar factories which have been closed. It will also be feasible to install additional new wet ethanol distillery (55 million usg) in Jamaica to utilize the already installed 70 million[22] usg dry ethanol facility at Jamaica. This would enable it to capture the expanding US ethanol export market without any import of wet ethanol.

To make UASB units viable a contingency plan would require attention on key elements of such solutions: (1) request CIDA to provide different type of assistance so that fertilizer from UASB unit can be sold; (2) give tax reduction to those trucks which will use methane instead of diesel; (3) all diesel not used by those trucks that use methane can be exported by refinery; (4) develop clear water fish pond for fresh water fish. Hence it is clear that even wastes in Jamaica in its present context offer potential for energy and contribute in energy savings by replacing an import component (see table 7 & 9 for the value of savings). It can be anticipated that by these power plants and UASB technology Jamaica would be able to improve its energy input/output ratios and treat some of its pollutants.

None of the above projects cane be viable if the land for sugarcane plantation continues to be allocated to the housing. From the view point of the integrated project, it will not get sugarcane or its residues as there will be no land to grow the sugarcane. Even if sugarcane is grown "Drought" or "hurricane" may be critically harmful to sugar factory but not to the operation of the BIG/ISTIG power plant. Demise of demand of ethanol for automotive use has no effect on this project as ethanol can be used in other industries. A cut off from EEC of wet ethanol can lead to a shortfall which can close Petrojam and Petronol. However, it may provide an incentive to Jamaica to source wet ethanol locally by building more distilleries. In addition EEC citizens will benefit if such a subsidy is stopped. Environmentally EEC will be forced to treat this wine which is not good for human consumption within EEC boundary which will provide jobs to EEC citizens.

It is anticipated that it would be feasible to grow other crops, to turn all distilleries into multi-cropping distillation facilities. It would also be feasible to introduce other types of cane plant such as sorghum. This is because, the productivity in the sugarcane sector as a whole would improve because of the anticipated change in attitudes of workers in the sugarcane sector towards

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22 Petrnol has 50 million usg capacity and Tropicana has 20 million usg hence total is 70 million less the capapcity of Petronol 15 million usg.

sugarcane and other cane crops, no longer considered a "whitemen's crops" due to the introduction of BIG/ISTIG plant.

It becomes clear from the (table 5) and (table 7) that no payment for import leaves the country during the thirty years of operation of the BIG/ISTIG plant except the payment of capital cost of power plant, its interest and funds for spare parts for the plant. The benefits in terms of export revenue enter Jamaica. In addition, saved import payment for oil can also be considered export earnings which otherwise would have left Jamaica to pay for oil. Inside Jamaica, farmers and plantation owners would receive additional revenue for the cane residues "barbojo". It can be anticipated that by reducing import of oil, Jamaica would reduce its trade deficit. By increasing exports of sugar, molasses, ethanol, bauxite and alumina, Jamaica would also be decreasing its trade deficit. Eventually this would lead to trade surplus on current account which in turn would make it possible to reduce the entire debt. This means it would improve its economic input/output ratios.

Considering the analysis above, as far as the energy and economics is concerned, in some form Jamaica would become sustainable by utilizing its own resources. I may not have achieved or even touched upon all essential aspects of sustainability for which further research may be required.

6.2 Approach and strategy of implementation and financing

Although this project is feasible, what would it take to implement it the light of several constraints?

There are three aspects of implementation. First, stages of implementation and technical improvements. Second, funds to support implementation. Third, institutional reorganization and redefining the task. Fourth, public acceptance of the project.

Stage 1 Stages of implementation
Projections of comprehensive plan for Jamaica

To implement this program, it would require full cultivation of all sugarcane on all the farms and plantations. (Table 3) shows the total land area that can be cultivated for sugar cane by ownership. (Table 9) shows how much of sugarcane would be needed for the 495 MW plants and how much sugar, ethanol, and electricity can be produced in the whole country. Table 9 shows how much of the same quantity can be produced if only the organized plantations are used.

At present the sugarcane production has reduced because of fixed market, based on quota, but if new uses and the markets are found sugarcane production can be increased. These markets do exists for about 145 products (see attached photocopy). For example ethanol can be added to gasoline to start a local gasohol program for existing vehicle fleet without any change in engine.

Brazil and Zimbabwe ethanol program have been successful [Goldemberg, Monaco, Macedo 1993] [Hall D., Rosillo-Cale, Groot P. 1992]. If Jamaican government decides to use 100% gasoline replacement, it would require modification in vehicle engines.

Stage 2 **Financing the projects**
Suggested way to implement and finance the project:

Step 1: Jamaica can introduce a gasohol program (10% ethanol additive) to be used by existing vehicle fleet. This would save 10% of that part of foreign exchange which is now used for importing crude oil to be refined as gasoline. Ethanol can be obtained from the Petronol-Petrojam output. This will save foreign exchange in two ways (1) by replacing gasoline ($3.5 million) and then (2) by saving part of wet ethanol cost ($4.93 million) for importing it from EEC.

Step 2: Jamaica can use this savings of ($8.43 million) to finance the modification of the vehicles so that they can use 100% ethanol. This will further save ($35.19 million).

Step 3: Jamaica then can introduce UASB waste treatment facility at a capital cost of ($1.05 million) including working capital of $0.05 million to produce methane, to treat sludge and to stop the wastes draining into the Kingston bay. Methane can replace diesel in the diesel operated fleet of trucks. This would generate revenue of ($ 0.22 million per year).

Step 4: Jamaica can use part of the ($35.19 million -step 2) (1) to finance the refurbishing of the Bernard lodge project to carry out steam saving measures by introducing new technologies; (2) to expand UASB reactors, and (3) to install the drainage system in and around Kingston area. When completed (2) and (3) can generate revenue of ($0.8 million) from methane in diesel savings and other byproducts including fertilizers of value ($1.5 million) at the most minimum. I cannot determine how much the project can charge for animal fodder or the Kingston metropolitan area for the waste. If it charges, then it can earn additional revenue.

Step 5: After steam saving measures are completed Jamaica can invest ($115 million) in the BIG/ISTIG plant. I assume lead-time for the power plant to start would be at least 3 years. By that time annual savings from gasohol, diesel and petroleum imports would amount to at least ($150 million) which is more than the capital cost required to install BIG/ISTIG plant. This plant will further save ($20 million) per year in foreign exchange and generate revenue of ($27.89 million) if the electricity is provided at 3c/kWh instead of at 5c/kWh. At the price of 3 cents the NPV of the cogeneration plant is still positive. At the price of 5c/kWh, the revenue would have been $46.49 million, so ($19.2 million) more than at 3 cents (see worksheet 3).

Step 6: This additional savings of ($39.2 million) made up of ($20 million) and ($19.2 million) can be used to expand the program further till it reaches entire Jamaica by which stage, it will generate 500 MW of power from biomass and export many other products. When the full program becomes operational, Jamaica will have sufficient power output and surplus funds to import energy efficient appliance to further its DSM program.

No other NRSE such as solar, wind, hydro or DSM can affect Jamaica's economy in such a comprehensive manner in so many sectors.

Stage 3 Public acceptability of the project
Redefining the technological goals

Now I shall look at this project from a social perspective. This is essential in order to ensure public acceptability of this project as there will be many people in Jamaica who will be involved and affected by the backward and forward linkage of this project.

However its implementation may require social perception and redefined technological goals in order to make them palatable to people who are annoyed at the whitemen. Can I change that and make them love them ? An important goal of consensus building in solving mega problems.

For example, current technological goals are to produce sugar when barbojo and bagasse are residue but if we redefine the goal by introducing new technology, then the goal is to produce electricity from bagasse and barbojo. They are fuel, and the sugarcane juice is utilized to produce biofuel "ethanol".

Then the surplus sugarcane juice is utilized to produce residue known as "sugar" which Jamaicans do not eat it, do not need and hence can be exported as the "residue" eliminating the argument known in literature of political economy as food versus fuel.

Then sugarcane is not the "whitemen's crop" but the "black men's crop ", and all the hard work they put in does not go in producing "sugar", the "black men's residue" but in producing the energy-electricity or the "black power ".

But how? The black power is produced by the technology conceived, invented and supplied by whitemen for the benefit of black men. This changes their perception of whitemen as the whitemen bring prosperity to blackmen.

Should this play of semantics trouble Western Governments and companies who can make US $575 million selling BIG/ISTIG plants, and another US $300 million in selling steam improving sugar and ethanol extraction technologies to Jamaica? At the same time Jamaica reduces the demand of oil by not importing it and thereby decreasing the price of oil which the West would love to see.

Success of BIG/ISTIG plant in Jamaica can be replicated in 80 sugarcane producing countries encouraging sustainable development through advanced technology.

Stage 4 Institutional issues and reorganization

If ethanol technology exists and ethanol market exists in Jamaica then how and why has Jamaica's biomass to energy conversion program failed ? Why did it not expand further into a bioenergy resource project ?

As I have mentioned, Jamaica did make an attempt to convert biomass into energy by establishing a wet and dry fuel grade ethanol. However, the program was not established to generate energy for Jamaica. Its purpose was simply to capture an export opportunity available under CBI by capturing an import opportunity provided by EEC.

A. Important facts to note

There are two interesting facts to note here. First fact is that a petroleum company (energy importing company) that acquired a sugar factory (agricultural company) to extract ethanol (energy) domestically. Second fact is that the dehydration facility (Petrojam) had more capacity (50m usg) than the capacity (15 m usg) of its own raw material supply unit of wet ethanol (Petronol). If this was the fact, then from where was the Petrojam planning to obtain its remaining wet ethanol? (50-15=35 million usg per year with an assumption that 15 m is produced by Petronol).

PCJ gave priority to the purchase of wine (ethanol) manufactured in Europe over ethanol manufactured in its own distillery and sugarcane factory, even when funds have been sunk in acquiring them. In such a case, why was the Petronol distillery even imported, when it was clearly known that EEC wine was cheaper ? Hence the goals of investment were not clear.

B. Conflict of institutional interests:

One of the reason may be that although physically the Petronol was a part of an integrated sugarcane project, yet in terms of institutional structure, the entire project was part of Petrojam and PCJ which cared least about the fate of the sugar factory or sugarcane plantations. PCJ imports petroleum for the country and has no interest in reducing its import activity which benefits many in the organization. In fact 8 million liters of ethanol was sufficient to blend it with gasoline to make gasohol for the entire Jamaica. Petronol was capable of producing 15 million liters, twice the amount needed. If the ethanol project had succeeded it would have forced PCJ to import less oil which was not in the interest of PCJ.

In brief, Petronol had lost its importance as a useful investment even before it had started. One of the reasons why Petronol was in loss was the lack of raw material (molasses) to produce wet ethanol. PCJ with the help of Jamaican government could have obtained more land for the sugarcane plantation at the Bernard Lodge to generate more crop, sugar, molasses and alcohol. Instead it gave away the fertile sugarcane land belonging to the Bernard Lodge to the housing authority to allocate it to poor people from the down town for a prefabricated housing project.

One would argue in favor of such a socially positive action. I am not here suggesting that low income families should not have been provided with the housing, but the question is where and how? Does it have to be on top of the sugarcane plantation (an energy source)? What I am describing here is a an example of isolated uncoordinated planning process in which each department pursues its politically targeted goal honestly and achieves it, but harms a larger economic, environmental and energy context without even understanding how it harms it.

C. So every one's interest was satisfied

Argument in favor of this arrangement in which sugarcane land was sold off would be that it benefited everyone (1) EEC got rid of its surplus wine. (2) Petrojam got cheap raw material from EEC instead of Petronol and produced dry ethanol for export as per CBI. (3) US also obtained cheap ethanol from EEC via Jamaica and other Caribbean nations under CBI (4) Housing department got the housing (5) Architect got his fees. (6) Construction company got the contract and made profit (7) People got the housing (8) Financial institutions created the successful loan portfolio (9) PCJ got rid of what the chairman of PCJ thought were unproductive sugarcane lands and (10) Farmers got rid of their land at the time when sugarcane was not selling and made more money.

D. Then who would have lost?

If this land continues to be sold off then the sugarcane industry, nation, national economy, local, national and global environment and the entire population of Jamaica would loose without understanding what they stand to loose.

The magnitude of damage beyond ethanol must be clear as shown in table 5. What happens obviously is that several possibilities of adding values to the sugarcane byproducts would be further destroyed, opportunity to generate energy would be lost. Jamaica would not be able to produce enough ethanol for local gasohol market nor for export market using its own resources. And so it would be the complete demise of energy generation from biomass.

As per my understanding this type of decisions and thinking arises from the way we measure the value of land.

6.3 Policy recommendations

A. Alternative measure of the value of land in energy units (mega joules) ?

I suggest calculating the total cumulative national benefits of derived out of land which can be measured in energy and monetary units rather than assuming the market value offered by speculators.

If the value of land is measured by different measures such as measuring in gigajoules and as the opportunity costs of cumulative national benefits, and then compared with the social need of providing housing, the result would be different. Housing can be provided anywhere, sugarcane cannot be grown anywhere.

Even if national benefits are less, does housing have to be provided on top of the sugarcane land ? Thus creating fuel versus settlement problem when food versus fuel problem does not exist in Jamaica as most of the people do not eat much sugar in Jamaica.

Land in downtown may have higher current monetary value than sugar plantation if they are auctioned. However land used for real estate does not generate all the products I have described. If the same land is auctioned, values quoted will be out of ignorance of its true national value among the people who are buying and selling. Land used for buildings does not generate recurring annual income in foreign exchange. It does not generate energy, gasoline substitute, methane gas and fertilizer replacing import. It does not provide raw materials for other industry. It does not grow food. It does not generate revenue or save foreign exchange, it does not improve energy balance and input/output ratios.

Whereas the land use for sugarcane does. Hence the price of land, can also be measured in terms of opportunity cost of cumulative national benefits and also in terms of potential energy content, hence in MJ/acre. In this particular case of The Bernard Lodge factory, the land per acre earns $1200 in export earnings per year and $1000 per year in import savings over several years giving far higher NPV when discounted than the same land used for housing for poor people, and higher NPV than the downtown for which this land is being sacrificed. So the price of land is $2200 per year in economic terms and the price of land is 8728 MJ/tc or 229808 MJ/acre annually or 40 barrels of oil per year. In addition, we must add all the positive externality costs which have been saved by not using the oil and interest not paid on future import of oil.

B Policy issue: How should the GOJ price the electricity and why ? A suggestion.

The question is should Jamaica charge 3c/kWh or 5c/kWh ? Social justice need not be the criteria in pricing of electricity. My suggestion is that 1) GOJ can charge bauxite industry 3c/kWh, so that its energy input cost becomes low to make it competitive (see section 3.8) 2) It can also charge 3c/kWh to the poor people who would use firewood so that they shift from firewood to electrical appliances[23]. Preservation of food by refrigeration at household level may reduce the amount of cooking; thus reducing use of firewood and deforestation. 3) Urban population with a higher income and industry producing luxury items can be charged 5c/kWh. 4) As an incentive, those industry that reduces the energy demand can be offered lower electricity prices.

6.4 General recommendations :

I recommend a multidimensional planning approach to solve a multidimensional problem of energy, economic and environmental problems. Here I present few elements of it, but the rest are left for further research.

1) Comprehensive planning process: There should have been a comprehensive review of the national resource endowment and its potential for the island nations or any nations, then evaluate the broader picture of energy, economics and resource management, allocate priority over the resource use which includes the land use, then make the sectoral plan complete with economic goals. This plan must be sustainable within the resource endowment of the country. This type of planning should be prepared by one section of the government whose survival or revenue depends on the outcome of total plan and not the individual sector. Not that such a plan cannot be changed but at least the consequences of the change can be estimated.

2) Energy charting: To assess the resources and plan the land use I suggest introduction of energy charting[24] in which indigenous and renewable energy resources should be located for a country. Geographic information system (GIS) as a tool can be utilized for this energy charting purpose.

3) New institutional arrangement - Energy, economic and environmental services

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23 Where will they get money to buy appliances is an another issue, may be through increasd employment and income which this projects do adress. In addition funds saved by not importing oil can be used to set up aplliance factories in Jamaica.

24 In case of biomass, this can take the form of a layer of soil survey, followed by a layer of most suitable crops, followed by a layer of potential energy content of each crops, this will enable planners to identify and allocate land for energy use. This land will have higher value in energy and economic terms than can be captured by its real estate value. Then the residual land not suitable for agriculture or the land with low energy content crops can be utilized for settlements or other economic activities. This type of survey can be carried out for solar energy, wind sites and hydro dams.

I recommend that we deviate from the conventional name - electric utilities, and form a broad institutional arrangement Energy, Economic and Environmental Services (EEES). This will help in synthesizing the goals.

3 A. Traditional process

Traditionally goals assigned to such an institution are to (1) balance the budget and external trade, (2) increase energy supply, (3) clean the environment, (4) improve economic indicators. In a traditional arrangement this would have been the task of different ministries which are then required to produce budget requirement approved by the ministry of finance after considering the advice of the ministry of economic development approves the fund which is then released by the treasury. In such an arrangement the Ministry of energy is responsible only for the supply of electricity irrespective of where input (oil) comes from. Only when the ministry of finance informs that there is no foreign exchange to import oil, they turn to indigenous energy resource.

3 B Redefining task in contradictory terms through privatization

I recommend redefining the tasks assigned to public organizations involved in energy generation in contradictory terms. Had it been that the utility was privatized and the currency was freely convertible then this would be the condition it would face. Though it may sound inefficient but suppose the goal assigned to the Ministry of energy was that it should generate energy from any source so long as it can do it at the lowest cost and find it's own foriegn exchange to pay for it. This means it has to first export in order to import. Suppose the ministry was told that it will be charged for any environmental clean up caused by its energy generation, task would have been even more difficult. Suppose that the staff were told their salary increment will be a percentage of net revenue it generates on the whole, then we have set up an internal checks and balance mechanism. The staff themselves will be more interested in checking the internal corruption and waste as they are more interested in the increased net final revenue figure.

Does it appear similar to private sector. Yes it is indeed. Industrial organizations and their executive constantly face such contradictory goals. A company cannot increase its import of raw material if it cannot generate sales revenue to pay for it, and that also in a business environment in which production costs are increasing and sales are declining.

3 C. Integration as an approach:

Projects that integrate are either not looked at or looked at incorrectly to give a reasonable attendance. Individual decisions do not always lead to a solution that is "socially optimal ". Threading interests of vested interests can be one of the goals.

Hence I suggest integrated, not decentralized and privatized, but an organization with interwoven institutional share holdings with suppliers, buyers, manufacturers, workers and farmers. In brief, threading interests of all the parties with vested interests. There are lessons to be learned from the private sector. For example, in case of Jamaica PCJ becomes share holder in power generation (JPS), and derives revenue from the sale of electricity and ethanol. Maximizing profit of JPS can only occur if the energy input cost is low. Oil is certainly not a low energy input but since PCJ gets share of profit out of JPS, it would like to encourage domestic low cost energy input.

Evaluating this projects from the criteria of cleanliness, robustness, safety, reliability and economic viability of an Integrated Energy System (IES)[25], this project can succeed in many ways.

1) Project involves multiple inputs (residue, wastes) and outputs (electricity, ethanol or ethane, methane, carbon dioxide, fertilizer) and frequently an intermediate product (such as sugar, molasses).

2) The project does not defy economics but improves economics as tables 6, 7,8, and worksheets 2,3,4,5,6 shows.

3) A more complete picture of IES depicts multiple paths for moving from a given set of resources to a required set of end energy forms. (Tabors 1990). For example, one can begin from sugar production, waste treatment, or energy generation from other agricultural residues. The choice of a path depends upon a variety of local factors: the availability and price of resources, the demand profile, pricing policy, capital stock already in place and environmental concerns (Tabors 1990). Preceding analysis has shown this clearly.

4) An IES may be best described as a system that acknowledges, accommodates, and exploits the interactions among major components in the energy system and the end use (Tabors 1990). This project acknowledges the existence of local resource, accommodates it by using the

[25] Integrated energy system (Tabors et al. 1990)

residues, and exploits the interactions among many units to generate sugar, molasses, ethanol, methane.

5) Economics provides the context. That is economics must be favorable. But the economics applies in a system whose boundaries are more appreciably larger than today's traditional definition. The underlying assumptions is that economic considerations are a dominant force in the system design (Tabors 1990). Economics was the reason why this project was conceived (see chapter 3). Economic analyses included the effect on sectors such as bauxite, sugarcane, environmental pollution which are far beyond a definition of a power generation project.

6) The old energy paradigm separated types of energy use, and the manufacturing industry from the energy supplying industries (Tabors 1990). In this alternative these boundaries have been clearly destroyed and hence given the name Integrated bioenergy resource project.

7) Only the government actions could bring them together, no evolutionary economics brings them into existence as long as the institutions and society do not work against them (Tabors 1990). I have shown that government and international agencies do and can work against this project and why they should not. I have shown that it is the economic viability based on market prices that is the key to the project.

8) When the value of products and byproducts changes, the system can be re-optimized to meet new challenges. Although IES as a whole is a complex system, its components are small and relatively simple. High level of security can be maintained, as the system is simple in inputs and environmentally sound because residues are costed and valued within the system (Tabors 1990). This project values and costs all products within the system through a series of simple components which are either existing (sugar factory, distillery) or proposed (UASB unit).

9) IES should act as a bridge between a good engineering idea and its final implementation. Government, regulatory, community, and business, needs to be aware of the advantages to be gained from putting the pieces together in a new pattern. Cleanliness is inherent in the system by taking residues in the system. (Tabors 1990). I have put different pieces together in new form and have shown benefits available to different sectors.

10) Different societies and different environments require different systems (Tabors 1990). This has been demonstrated by the fieldwork analysis of institutional, labor, and policy context and solutions are suggested.

11) In the end this project sets an example of the goal of IES consortium to complete a detailed monograph of experience of IES in different countries.

6.5 Policy lessons and recommendations with global replicability value

There are 80 sugarcane producing or biomass surplus countries where such an integrated bioenergy resource project can be implemented. There are lessons to be learned from the preceeding analysis of the case of Jamaica which can be replicated in other countries. They are described below.

1) Integration of ownership rather than the privatization of individual units as proposed by The World Bank will make it feasible to reduce the price of electricity and to maximize economic development. Integration of ownership may be a better approach to ensure its viability. It also raise a question as to whether privatization of energy sector should be followed blindly from utility to the supply of fuel ?

2) To reduce the price of electricity from sugarcane residues would require an increased production of ethanol, sugar and molasses.

3) Simply enacting a law banning cane burning in order to solve the environmental problem of cane or firewood burning may or may not be complied. However if cane or other residues fetches additional revenue as fuel to the BIG/ISTIG plants, then the chances of cane burning are less because it would be as good as burning dollar bills and such a behavior may not be expected from either poor farmers or rich capital seeking plantation owners.

4) It is predicted here that the specifications associated with financial incentive would ensure the supply of barbojo of desired quantity and quality. I also infer that farmers may not shift to different crops due to added value offered by residue, ensuring supply of desired crop and residue.

5) The indirect fallout of this project was addressing deforestation. One of the benefit of this project is that by reducing the price of electricity, this project makes electricity affordable to low income consumers. In addition, it would create jobs, make exports competitive and address general economic development if repeated throughout Jamaica. In such a situation even rural people would prefer and would be able to afford appliances which can use other forms of energy such as electricity, rather than using a direct smoke producing firewood.

6) Biomass as an energy resource will have the least operational problem and more comprehensive benefits when compared with other NRSE in tropical developing countries (Table 8). However, NRSE are context dependent and must be assessed on a case by case basis which can be the suggested direction for further research.

7) It is preferable to choose biomass which has higher sucrose contents and more carbon elements so as to obtain maximum byproducts so that price of electricity can be reduced through an integration of producing units.

8) The case of EEC wine export and CIDA fertilizer export provide a clear lesson for any international aid agency, that if a country can help itself, it may be desirable to allow it, so that tax payers of the donor country do not suffer. In addition it may force the receiving country to become efficient to be self-sufficient.

9) If the market for BIG/ISTIG technology is identified, analyzed and justified by a feasibility analysis like this, the manufacturer and its country may be willing to sell the technology and the technology can be available to a developing country as it benefits both north and south.

10) There is a need to form an "international cooperative"[26] as a tool of environmental diplomacy[27] and as a tool to integrate farmers in a global market by equity participation. Such a cooperative can have wide share holding to compete with "multinational corporation". Integration of ownership to include the manufacturer of advanced technology as a share holder along side a small farmer ensures supply of spare parts and raw materials.

11) Environmental compliance without criticism or infringing on national sovereignty can be obtained by ensuring operationality through equity participation in such projects which use NRSE, treat pollutants, and address poverty and deforestation. Then the share holding becomes a tool of environmental diplomacy.

---

26 A term derived by Jinraj Joshipura 1986 for the Palm Kernel Oil Coperative in NIgeria. A project which included the Malaysian machine manufcturers, local governemnt and local farmers as shareholders.

27 A term borrowed from the tiltle of the book of Prof. Lawrence Susskind called, " Environmental Diplomacy."

12) By borrowing concepts of "cooperative" from the left and "capitalistic structure of incentives" from the right, this project encourages a holy alliance of right and left to replace the unholy alliance of right and left[28] of the post cold war era.

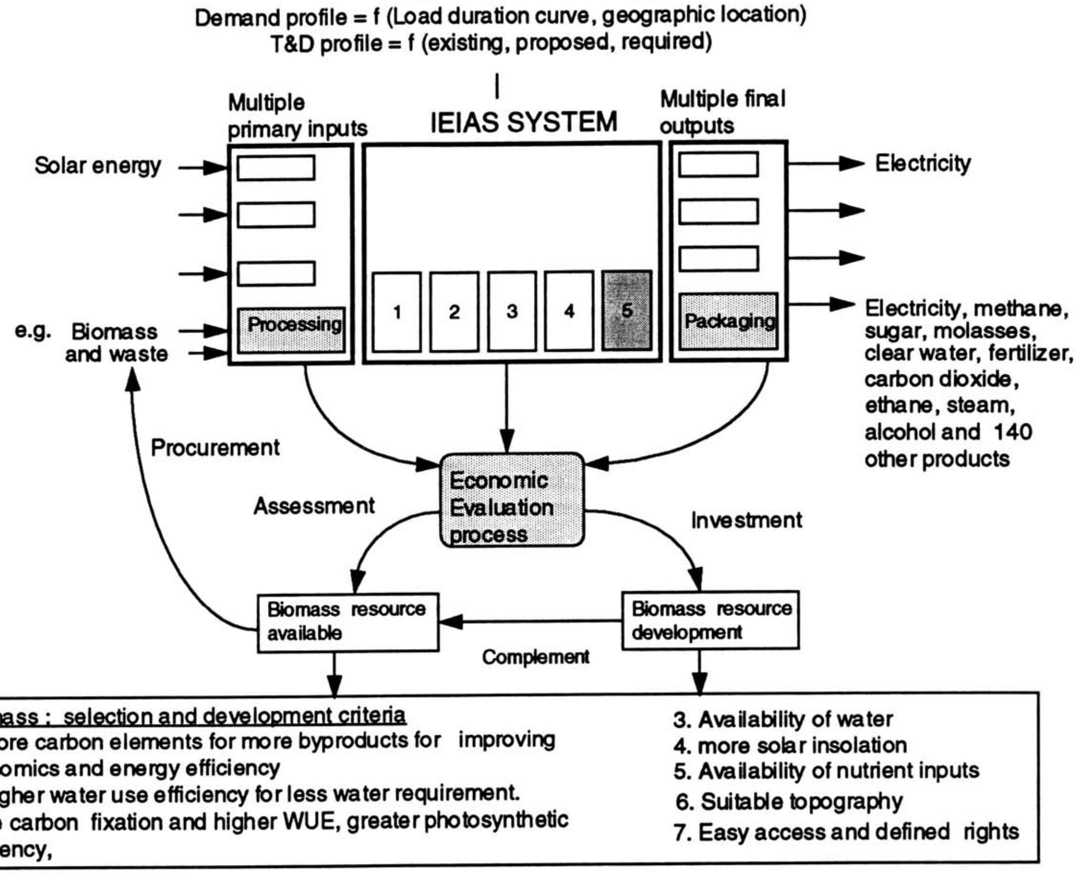
13) The lesson to learn here was that workers hated the technology because of the products it produced. Hence attitudes, perception, lethargy etc. of workers has no relation to the level of advancement of technology so long as it can offer benefits to them. These benefits are not otherwise perceived through social engineering but may instead require engineering the "sociology ". It may also require renaming the goals. This may require filling in the future Input/output tables with costs and benefits accessible through technological perception and not through normal human perception.

14) The key to success here was the introduction of advanced technology and indigenous resource utilization as the reason for substitution of fuel for energy generation. Even indigenous resource utilization can be a valid reason; even among NRSE only a few really benefit comprehensively and hence can be the reason for substitution.

15) General model for replicability is shown on the next page 82 in which biomass is one of the fuels in the integrated energy system in which other fuels and their energy conversion processes are also integrated. By integrating sugarcane sector and waste unit, it becomes Integrated Energy, Industry and Agricultural System (IEIAS).

28 A term borrowed from the title of a paper by Prof. Bishwapriya Sanyal.

General model - Integrated bioenergy resource model



References: IEIAS = Integrated energy, industry and agricultural system Box 5 = non energy production process (by Jinraj Joshipura)
IES = Integrated energy system . Box 1 = Transformation process A Box 2 = Industrial gases
Box 3 = Gas saparation, Box 4 = Transformation B (Tabors et al. 1990)

Source: © Jinraj Joshipura 1993

Interviews:

A.

1.		Program assistant (development section), Canadian High Comission, Kingston, Jamaica
2.	Chevannes Barbara	Public relation officer, Ministry of Public Utilities and Transport
3.	Dr. Minnot Dennis	Energy consultant, Enerplan Lt
4.		General manager, PCJ,
5.		Processing manager
6.		Plant manager, Petronol Ltd.
7.	Lakasingh Effie	Director, Jamaica agrochemicals Ltd. - trader
8.		(Former managing director, PCJ)
9.	Welsh Dennis	Plant manager, Jamaica ethanol processing Ltd. (formerly Tropicana Ltd.)
10.	Managing Director	Petroleum Corporation of Jamaica (PCJ).
11.	Program Officer	USAID
12.	J. Anthony O'connor	National Water Comission

I cannot forget the following.

B.

13. Various taxi drivers
14. Sugarcane farmers and workers
15. Staff of Petronol
16. Local market traders

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	Table 1	**CRITERIA OF COMPARISON**	
		Between various levels, forms, and sources of energy	
	CRITERIA	**RENEWABLE**	**NONRENEWABLE**
			(conventional such as coal and oil)
	Criteria 1 to 18 by author - Jinraj Joshipura		
1	**Type of energy**	Direct solar energy and in different	Solar energy in different forms such
		forms such as biomass, hydro, wind	as coal, gas, oil
2	**Time required for**		
	formation	Less than 500 years	More than 500 years
3	**Source**	Available in every country,	Available in few countries or regions
		region or local area	or local area
4	**Form of energy**	Solid, liquid, or gaseous	Solid, liquid or gaseous
5	**State of energy**	As a current, or flow of energy	In a dormant state - concntrated stock
6	**Supply prospect**	Abundant and infinite - supply	Abundant at present but finite in stock
		limited by economic and	Supply is ultimately limited by stcok
		economic constraints	
7	**Geographical dispersion**	Above and below surface	Below surface
		Site specific but can be transported	Site specific but can be transported
8	**Ease of availability**	Extremely easy to obtain	Requires extraction
9	**Ease of acessibility**	Easily accessible	Requires effort to extract, transport,
		Biomass used as traditional fuel	store, refine and use
		Solar energy for water heating	
		Wind as windmills	
10	**Location for use**	Site and society specific,	General and international use
11	**Scale**	Small scale economic, large scale	Large scale often improves supply
		may present difficulties	costs, large scale frequently favoured
12	**Manpower requirement**	Large and varied	Large and varied
13	**Important disciplines**	Bioscience, physics, agriculture	Physics, geology but not agriculture
14	**Linkages to rural area**	Extensive sends revenue to rural raea.	Linkage extracts revenue from rural area
15	**Participation of unskilled**	Extensive	Little
	rural labor		
16	**Type of economic activity**	Decentralised industries	Centralised and monopolised industry
17	**Types of systems**	Self sufficient - low to high	Interdependent on higher technology
		technology	
18	**Property right issues**	Solar and wind - no owneship rights	Coal and oil has ownwership rights
19	**Environmental pollution**	Little environmental harm	Extensive environmental pollution
			air, water, soil etc.
	Criteria 19 to 24 as per Twiddle J. in " Renewable Energy Resources".		
20	**Skills required**	All types of skills required including	All types of skills required excluding
		agricultural and forestry	agricultural and forestry
21	**Environmental damage**	At a moderate scale and reversible	Permanent damage common from
			mining. Deforestation and ecological
			sterilisation from excessive air pollution
22	**Safety consideration**	Site specific hazardous possible	Most dangerous when fault occurrs in
		Safe when not in operation	the systems
23	**Intensity at innitial stage**	Low intensity - dispersed:	Released at ~100kWm minus raise
		~300m minus raise to 2 or less	to 2 and more
24	**Variation and control**	Fluctuating: best controlled by	
		change of load using	
		feedforward control	
	Source: Criteria 1 to 18 by author - Jinraj Joshipura and 19 to 24 based on information from [1] Twiddle J.,		
	" Renewable Energy Sources". spon. 1986. page 4		

	Table 2	SURVEY OF POTENTIAL OF BIOMASS IN JAMAICA			
	Landuse	**Miles**	**Square miles**	**Acres**	**% of total land area**
1	Lenth	146			
2	Width	51			
3	Coast line	550			
4	Total land surface area		4400	2,816,000	100%
	Less				
5	Mining (mostly bauxite)			7,000	0.25%
6	Total settlement area - Urban			100,000	3.55%
7	Total industrial area				
8	Total agriculture including pastures			1,258,000	44.67%
9	Barren			4,000	0.14%
10	Swamp			50,000	1.78%
11	Natural range and grass land			103,000	3.66%
12	Forest cover			655,000	23.26%
13	Additional natural forest			538,000	19.11%
	cover excluding food tree				
	Total			2,715,000	96.41%
	Difference in data			101,000	3.59%
14	Total forest cover				
15	Gazzeted forests icluding			274,000	9.73%
	Crown lands			30,000	1.07%
	Crops				
1	Sugarcane			168000	5.97%
2	Banana			84000	2.98%
3	Coconut			100000	3.55%
4	Coffee			15000	0.53%
5	Citrus			25000	0.89%
6	Cocoa			27000	0.96%
7	Pineapple			1300	0.05%
8	Red peas			6500	0.23%
9	Pigeon peas			7000	0.25%
10	Peanuts			1000	0.04%
11	Potatoes and yams			18200	0.65%
12	Maize			8000	0.28%
13	Tobacco			1900	0.07%
	Sources: 1. National Atlas of Jamaica. U.N. Special Fund Project				
	2. Economic and Social Survey, Jamaica 1991				

	Table 3		DISTRIBUTION OF SUGARCANE ACREAGE					
	Name of Parish	Name of Estates	Acres of sugar cane estates	Total for parish	Acres of sugar cane farmer's	Total for parish	Total acreage	Total for Parish
1	**Claredon**	Monymusk	18000		7000		25000	
		New Yarmouth	1300		9000		10300	
		Sevens	3200		9000		12200	
				22500		25000		47500
2	**St. Catherine**	Worthy park	1600		3200		4800	
		Innswood	5500		6000		11500	
		Bernard lodge	8000		4000		12000	
		United estates	2300		4000		6300	
				17400		17200		34600
2A	**Total acreage around the Bernard Lodge**							**82100**
3	**Westmoreland**	Frome	14000	14000	16000	16000	30000	30000
4	**Hanover**				8200	8200	8200	8200
5	**Trelawny**	Hampden	3000		5000		8000	
		Long Pond	3900		4000		7900	
				6900		9000		15900
6	**St. James**				3800	3800	3800	3800
7	**St. Thomas**	Serge island	2200		3000		5200	
		Duckenfield	4100		2100		6200	
				6300		5100		11400
8	**St. Elizabeth**	Appleton	2900		4000		6900	
		Holland	2500		500		3000	
				5400		4500		9900
9	**St. Mary**	Gray's inn	1700	1700	3000	3000	4700	4700
10	**St.ann**	Richmond	1700				1700	1700
		Llandovery						
	Total		75900	74200	91800	91800	167700	167700
	Source:	Rearranged and produced from the information from the National Atlas of Jamaica. page 35. UN Special Fund Project.						

Table 4 **INTEGRATED ENERGY AGRICULTURE AND ECONOMIC DEVELOPMENT PROJECT**

(Technical - Input/output table for material flow which can be measured either in energy consumption or production)

Receiving sectors (horizontal axis)

	Producing sectors (listed below)	1 Land	2 Plantation	3 Market	4 Sugarcane factory	5 BIG/ISTIG plant	6 Distillery	7 Environm. unit	8 Dehydration plant	9 Gasohol project	10 Gas station	11 Vehicles	12 Electric utility	13 Government	14 Atmosphere	15 Aquatic Resources
1	Land		Nutrients													Drained water
2	Plantation farms	Barbajo 20%			Sugarcane	Barbajo 80%										
3	Market (external input)	Additional fertilizer	Insecticides herbicides		Equipment	Equipment	Equipment Yeast	Equipment	Equipment	Equipment	Equipment	Lubricants Spares	Equipments Spares			
4	Sugarcane factory			Sugar		Bagasse	Sugarcane juice Molasses							Saved oil		
5	BIG/ISTIG plant	Char as fertilizer		Plant scrap	Steam		Steam Electricity						Electricity	Saved oil	Carbon dioxide	
6	Distillery			Plant scrap		(1)Bagasse (2) Cane residues		Vinasse	Ethanol	Additive					Carbon dioxide	
7	Environmental unit	Digetsed vinasse for fertili-irrigation	Dried solids							Automatotive methane						
8	Dehydration plant			Plant scrap							Gasohol					
9	Gasohol project	Spillover ethanol		.							.	Gasohol				
10	Gas station	Spillover ethanol														
11	Vehicles	Spillover														
12	Electric utility	ethanol		Scrap												
13	Government															
14	Atmosphere	Rainwater				Oxygen	Oxygen									
15	Aquatic resources	Rainwater	Water		Water	Water	Water	Water		Water		Water				

Source: By author by combining 11 years of work experience with the information about BIG/ISTIG technology, sugarcane industry, UASB technology obtained from (Williams, Larson 1993), (Lettinga, Haandel 1993), (Goldemberg, Monaco, Macedo 1993), (Ogden J. Fulmer M.)

	Table 5	Explanation and derivation of bioresource energy project requirements								
	ITEMS	**Formula**	**Quantity**	**Units**	**Price**	**Units**	**Amount**	**Paying sector**	**Receiving sectors**	**Import Export**
A	**To produce electricity**									
1	In cogeneration mode for 133	(97.4*1000*24*133)	310900800	kWh	$0.03	kWh	$9,327,024	Utility	BIG/ISTIG	
	days at the rate of 97.4 MW (1)									
2	In power mode for 232 days at	(111.2*1000*24*232)	619161600	kWh	$0.03	Kwh	$18,574,848	Utility	BIG/ISTIG	
	the rate of 111.2 MW (1)									
	Total		106	MW						
B	**BIG/ISTIG plant fuel**									
	requirements									
3	Bagasse supply required for									
	133 days (2)	133*24*57.3	182902	tons	$2.06	ton	$376,777	BIG/ISTIG	Sugar fac.	
4	Barbojo supply required for									
	232 days (2)	232*24*57.7	321274	tons	$4.99	ton	$1,603,155	BIG/ISTIG	Farmers	
C	**Sugarcane required**									
5	Sugarcane required to produce	182901/.283	646293	tons						
	bagasse at the rate of 283 kg/tc									
	(3)									
6	Sugarcane required to produce	321273/.33	973555	tons						
	321273 tons of barbojo at the									
	rate of 330 kg/tc - caribbean									
	productivity (4)									
7	Hence sugarcane required to		973555	tons	$8.00	ton	$7,788,440	SF. or	Farmers	
	run BIG/ISTIG plant							Distillery		
D	**Land requirement for**									
	sugarcane									
8	Land required to produce	973555/26.33	36975	acres						
	sugarcane at the rate of 26.33									
	tons of sugarcane per acre-									
	Jamaican productivity 1991. (5)									
9	Land available around plant		82100	acres						
	(see table 3)									
E	**Sugarcane juice available**									
	for various product mix									
10	1784850 tons of sugarcane can	973555*1	973555	tons						
	produce sugarcane juice at the									
	rate of 1ton/tc (2)									
F	**Wet ethanol**									
11	Ethanol per ton of cane (1)		70	liters						
12	Ethanol per ton of cane	70*.2642	18	usg						
13	Petronol capacity 15 million		15000000	usg/yr	$0.57		$8,550,000	Petrojam	Petronol	
	usg per year (UNDP report)	15000000*3.78	56700000	liters/yr						
14	Petrojam sales to United States	135000000	13500000	usg/yr	$0.23		$3,105,000	USGC	Petrojam	Export
	Gulf Coast market -									
	dry ethanol at $.9/usg (5)									
15	Sugarcane juice required for	56700000/70	810000	liters						
	ethanol at the rate of 70 liters/tc									
	or ton of juice									
16	Surplus juice	973555 - 810000	163555	liters						
G	**Use of surplus sugarcane**									
	juice									
17	Producing A+B sugars at the rate	163555*.096	15701	tons	$266.00		$4,176,540	World	Sugar fac.	Export
	of 96 kg/ tc of ton of juice (1)							market		
18	And producing molasses at	938850*.035	5724	tons	$60.00		$343,466	World	Sugar fac.	Export
	the rate of 35 kg/ton							market		
	of juice or tc (2).									
H	**Total revenue derived from**									
	one acre of land									
1	For the project (excluding	A1+A2+F13+F14+								
	UASB revenue)	G17+G18					$44,076,878			
	Source : By author based on information from (1) Ogden J., Fulmer M. 1990 (2) ogden, Williams, Fulmer 1990.									
	(3) Goldemberg, Monaco, Macedo 1993. (4) Williams, Larson 1993 (5) ESSJ (6) UNDP report 1992.									

	Table 6	Energy flows in the Integrated Bioenergy Resource Project							
	Item	Units	Energy content	Average values Input	Average values Output	Ratio	Higher values Input	Higher values Output	Ratio
A	**Sugarcane plantations**								
1	Sugarcane production	MJ / tonne cane		221.75			197.46		
2	Barbojo	MJ / tonne cane			346			630	
	RATIO 1					**1.56**			**3.19**
B	**Distillery**	MJ / tonne cane		70.1			40.56		
	Ethanol	MJ / tonne cane			1707.11			1941	
	Bagasse surplus	MJ / tonne cane			175.14			328.55	
	RATIO 2					**7.63**			**12.18**
C	**Sugar factory**								
1	sugar	MJ / tonne cane			1801.14			1801.14	
D	**Waste treatment plant**								
	Methane from distillery	MJ / tonne cane			431.11			431.11	
	Methane from Kingston	MJ / tonne cane			417.78			417.78	
	Fertilizer								
	Total	MJ / tonne cane		291.85	4878.27		238.02	5549.59	
	RATIO 3					**16.72**			**23.32**
E	**Cogeneration plant**								
1	Fuel - bagasse and barbojo	MJ / tonne cane		6250			6250		
2	Electricity	MJ / tonne cane			2401.2			2687.5	
3	Steam								
	RATIO 4 (for E only)					**0.38**			**0.43**
	RATIO 5 (total)	MJ / tonne cane		6541.85	7279.47	**1.11**	6488.02	8237.09	**1.27**
F	**Steam demand**			**Demand**	**Supply**				
	After conservation measures				BIG / ISTIG				
	in sugar factory and distillery								
	are implemented								
1	Medium pressure steam			223 kg/tc	235 kg/tc				
	(2.1 Mpa, 300 centigrade)								
2	Low pressure steam			223 kg/tc	235 kg/tc				
	(0.25 MPa, 127 centigrade)								
G	**Environmental emission**								
1	Sulfur dioxide			0	0				
	Note: 1	All products out of waste from Kingston are not included as the energy efficiency							
		of only this project is being considered. In such a case ratio of energy I / O will rise.							
		Energy content of steam and fertilizer are not included in the ratio							
	Note: 2	Data on energy input in the production of BIG / ISTIG plant and sugar factory							
		are not available							
	Source: For A1, B1, B2 (Goldemberg, Monaco, Macedo 1993) for D1,D2 (Lettinga, Haandel 1993), For E1, E2, F1, F2								
	Larson 1993, Ogden, Fulmer 1990),								

Table 7		REVENUE DERIVED BY DIFFERENT SECTORS ANUALLY											
		Table below refers to the integrated bioresource energy project at the Bernard Lodge factory											
		(Box defines the country hence any number outside is leakages from the Jamaican economy)											
Import		Item	Quantity	Units	Price	Units	Plantation owners & framers	Sugar factory	Distillery	Cogeneration plant	Waste treatment plant	Total funds flow in the economy	Export
Investment		Land	36975	acres									
once	1	Sugarcane	973555	Tons	$8	Per ton	$7,788,440					$7,788,440	
$ 115 m													
	2	Sugar	15701	Tons	$266	Per ton		$4,176,466				$4,176,466	$10,640,000
	3	Barbojo	321274	Tons	$4.99	Per ton	$1,603,157					$1,603,157	
			3064954	GJ		GJ							
	4	Bagasse	182902	Tons	$2.06	Per ton			$376,778			$376,778	
			1766833	GJ		GJ							
	5	Molasses	5274	Tons	$60	Per ton		$316,440					
	6	Electricity	3.11E+08	kWh/133	$0.04	kW				$12,436,032		$12,436,032	
			6.19E+08	kWh/232	$0.04	kW				$24,766,464		$24,766,464	
	7	Steam	132172	Tons	$1.00	per tons				$132,172		$132,172	
	8	Ethanol	15000000	Usg	$0.54	Usg			$8,100,000			$8,100,000	$8,100,000
			56779500	litres	$0.14	litres						$0	
	9	Stillage	7.95E+08	litres	$0.20	litres					$1,589,826	$1,589,826	
		as fertilizer										$0	
	10	Methane	1674	Tons	$132	per ton					$220,968	$220,968	
	11	Methane	6139	Tons	$132	per ton					$810,348	$810,348	
		(Kingston)										$0	
			Total for each sector				$9,391,597	$4,492,906	$8,476,778	$37,334,668	$2,621,142	$62,317,091	$18,740,000
	12	Savings from not importing oil for power and gasoline										$16,230,000	$16,230,000
	13	Total benefits										$78,547,091	$34,970,000
	14	Benfits per acre of land				$78547091/36975 acres						$2,124	$946

Table 3 COMPARISON OF VARIOUS RENEWABLE RESOURCES

(With reference to their operation in Jamaica or other tropical countries such as Thailand, Zaire, Panama etc.

Source: Jinraj Joshipura 1993

	Criteria	Biomass	Solar	Wind	Hydro	DSM	Tidal	Distribution & transmission systems
1	**Availabilty**	1. Plenty of biomass available	1. Irregularity due to cloud cover	1. Irregular due to weather	1. Not enough in dry season	1. Requires import of equipment	1. Not regular	1. Partially available
2	**Effect of increased rain and less less heat**	2. Increases biomass	2. Decreases solar insolation	1. Increases irregularity, humidity and cross wind currents 2. Obstructs the wind turbine operation	1. Increases hydro capacity			1. Water puddles and fallen cables can cause shock
3	**Effect of decraesed rain and more heat**	1. Decreases biomass 2. Increases deforestations	1. Increases solar insolation	1. Increases wind currents and turbulence 2. Creates differential pressures	1. Decrease hydro capacity			1. Increased heat increases electrical consumption and load
4	**Sources of machinery**	1. 50% available in Jamaica	1. Not available - import and higher unit cost	1. Not available - imoport and higher unit cost	1. Local capacity available	1. Import required		Not available - import required
5	**Local technical capacity**	1. Available locally	1. Partially available	1. Partially available	1. Local capacity available	1. Partially available	1. Not available	1. Available for repair maintenance
6	**Effect of hurricane**	1. It increases fallen biomass	1. Destroys the solar panels	1. Wind turbines become inoperable due to turbulence	1. Heavy rains causes landslide and floods			1. Disrupts the distribution & transmission - fallen cables
7	**Distribution**	1. Decentralized	1. Decentralized	1. Decentralized	1. Decentralized and centralized	1. Decentralized and centralized	1. Concentrated	1. Transmission problems
8	**Transmission network**	1. Smaller transmission 2. Dispatchable - supply base load	1. Not dispatchable due to variation in solar insolation	1. Transmission system have to be updated as per the ultrawind scenario 2. Not dispatchable	1. Concentrated 2. Dispatchable	1. Conserves installed transmission capacity	1. Not dispatchable	1. Problems of location and land acquisition 2. Higher Megawatts demand bigger transmission cables 3. Better technology & control
8	**Effects of bugs and mosquitos**	1. Part of ecosystem hence it has no effect	1. Creates rough surface increases maintenance	1. It can create a rough surface	None	None	None	None
9	**Effects of air density**			1. It creates different pressures				
10	**Visual effects**	1. Biomass development enhances the beauty	1. Solar panels may reflect solar rays and may not be a good sight	1. Not good sight for tourists	1. Excellent tourist and picnic spot - visaully better	1. Imported designs do not match local vocabulary	1. Negligible	1. Not a good sight
11	**Effect on land use**	1. Promote land use for biomass development	2. land areas may be cleared of trees to receive solar insolation	1. Cleared lands for wind turbines	1. Occupies large tracts of lands - effects ecology at mcro level			1. Centralized energy generation requires more transmission and occupies more land
12	**Risks & costs**	1. Promotes reforestation	1. Use promotes deforestation	1. Promotes deforestation	1. Breaking of dams dykes 2. Over flooding 3. Displacement of people	1. Imported equipment need imported spares	1. Continued import for maintenance	1. Fallen cable in rain - possibility of electrical shocks - continous repairs, imports and costs
13	**Energy -stor.**	Not required	Required	Required	Extensive storage	Required	None	Not applicable

Table 9	Potential annual revenue and it's distribution in the whole country if 495 MW (the entire demand) of electricity is produced using biomass													
Import		Item	Quantity	Units	Price	Units	Farmers	Plantations	Sugar factory	Distillery	Cogeneration plant	Waste treatment plant	Total flow of funds in the economy	Export revenue
Investment	1	Sugarcane												
once		Plantation	1998447	Tons	$8	Per ton		$15,987,576					$15,987,576	
$ 575 m		Farmers	2417094	Tons			$19,336,752						$19,336,752	
for five	2	Sugar	430684	Tons	$266	Per ton			$114,561,944				$114,561,944	$114,561,944
BIG/ISTIG	3	Barbojo	659488	Tons		Per ton								
plants			6291511	GJ	$1.45	GJ		$9,122,691					$9,122,691	
			797641.02	Tons										
			7609495	GJ	$1.45	GJ	$11,033,768						$11,033,768	
	4	Bagasse	736714	Tons		Per ton								
			7116653	GJ	$1.25	GJ				$8,895,817			$8,895,817	
	5	Molasses	0	Tons	0	Per ton								
	6	Electricity	1243603200	kWh/133	$0.04	kW					$49,744,128		$49,744,128	
			2476646400	kWh/232	$0.04	kW					$99,065,856		$99,065,856	
	7	Steam	577093	Tons	$1.00	per tons					$577,093		$577,093	
	8	Ethanol	60000000	Usg	$0.54	Usg				$32,400,000			$32,400,000	$32,400,000
			227118000	litres	$0.14	litres								
	9	Stillage	3179652000	litres	$0.20	litres						$6,359,304	$6,359,304	
		as fertilizer												
	10	Methane	25349	Tons	$132	per ton						$3,346,080	$3,346,080	
			Total for each sector				$30,370,520	$25,110,267	$114,561,944	$41,295,817	$149,387,077	$9,705,384	$370,431,009	$146,961,944
		Savings from not importing oil for power and gasoline											$323,650,000	$323,650,000
		Total benefits											$694,081,009	$470,611,944

	Worksheet 1	**Import of oil as a % of import and export projected over 15 years**															
M.	**Oil import as a % of total import**																
	All figures US$'000,000)	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**
1	Total import kept constant	1799	1799	1799	1799	1799	1799	1799	1799	1799	1799	1799	1799	1799	1799	1799	1799
2	Oil import increases by 3%	323.64	333.3	343.3	353.7	364.3	375.2	386.4	398	410	422.3	434.9	448	461.4	475.3	489.5	504.2
	per year at a $ 17.4/barrel																
3	Oil import as % of total	17.99	18.53	19.09	19.66	20.25	20.86	21.48	22.13	22.79	23.47	24.18	24.90	25.65	26.42	27.21	28.03
4	Oil import increases by 3%	372.00	383.2	394.7	406.5	418.7	431.2	444.2	457.5	471.2	485.4	499.9	514.9	530.4	546.3	562.7	579.6
	per year at a $ 20/barrel																
5	Oil import as % of total	20.68	21.30	21.94	22.60	23.27	23.97	24.69	25.43	26.19	26.98	27.79	28.62	29.48	30.37	31.28	32.22
N.	**Oil import as a % of total export**																
1	Total export kept constant	1145	1145	1145	1145	1145	1145	1145	1145	1145	1145	1145	1145	1145	1145	1145	1145
2	Oil import increases by 3%	323.64	333.3	343.3	353.7	364.3	375.2	386.4	398	410	422.3	434.9	448	461.4	475.3	489.5	504.2
	per year at a $ 17.4/barrel																
3	Oil import as % of total	28.27	29.11	29.99	30.89	31.81	32.77	33.75	34.76	35.81	36.88	37.99	39.13	40.30	41.51	42.75	44.04
4	Oil import increases by 3%	372.00	383.2	394.7	406.5	418.7	431.2	444.2	457.5	471.2	485.4	499.9	514.9	530.4	546.3	562.7	579.6
	per year at a $ 20/barrel																
	Oil import as % of total	32.49	33.46	34.47	35.50	36.57	37.66	38.79	39.96	41.16	42.39	43.66	44.97	46.32	47.71	49.14	50.62

	Worksheet 1	**PETROLEUM CORPORATION OF JAMAICA**										
		Fuel grade ethanol production										
		Economic analysis model										
	After adjusting for inflation (51%) and different exchange rates											
A	**Assumption basis**											
1	Petronol capacity	MMusg/yr	15.00									
2	Petrojam capacity	MMusg/yr	40.00									
3	Yield of dry ethanol from wet		0.95	95%								
	ethanol, by volume											
B	**Petronol** Wet ethnol production cost	(All CBI value added qualifying up to the limit of $ 1.25/usg)										
1	Different exchange rates			J$8=1$	J$22=1$	J$36=1$						
2	Fixed		MM$/yr	0.20	0.11	0.07						
3	Variable		$/usgal	1.39	0.76	0.47						
C	**Petrojam** Dry ethanol production cost											
1	Fixed cash		MM$	0.75	0.41	0.25						
2	Fixed CBI qualified		MM$	1.22	0.67	0.41						
3	Variable (All CBI)		$/usgal	0.13	0.07	0.04						
D	**Petronol capital investment**											
1	Net breakup sale value	$	3.00	Million								
2	Waste treatment plant	$	4.00	Million								
E	**Sensitivities vs. base**											
1	USGC Mogas ulr price		100%									
2	Caribbean wet ethanol price		100%									
3	EEC wet ethanol price		100%									
4	Sales volume dry ethanol tons to US		100%									
F	**Prices**		**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**
1	USGC Mogas (ULR) price	$ BBL	25.16	22.28	23.08	24.15	25.36	26.67	28.08	29.6	31.10	30.77
2	USGC Mogas (ULR) price	$ usgal	0.60	0.53	0.55	0.58	0.60	0.63	0.67	0.70	0.74	0.73
3	Gasohol subsidy, gross	$ usgal	0.54	0.54	0.54	0.54	0.54	0.54	0.54	0.54	0.54	0.54
4	Term, transport, profit,	$ usgal	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19
5	Net subsidy effect USGC	$ usgal	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35
6	USGC ethanol value for CBI	$ usgal	0.95	0.88	0.90	0.93	0.95	0.98	1.02	1.05	1.09	1.08
7	Freight, Kingston to USGC	$ usgal	0.05	0.05	0.05	0.06	0.06	0.06	0.06	0.06	0.06	0.06
8	Ethanol FOB Kingston	$ usgal	0.90	0.83	0.85	0.87	0.89	0.92	0.96	0.99	1.03	1.02
	Gasohol											
9	Ethanol for domestic	$ usgal	0.63	0.56	0.58	0.60	0.62	0.65	0.69	0.72	0.76	0.75
10	Ethanol for domestic	J$usgal	22.68	20.16	20.88	21.60	22.32	23.40	24.84	25.92	27.36	27.00
G	**Caribbean wet ethanol**	$ usgal	1.11	1.03	1.06	1.09	1.12	1.16	1.2	1.24	1.28	1.27
H	**European wet ethanol**	$ usgal	0.54	0.52	0.53	0.53	0.54	0.55	0.56	0.57	0.58	0.58
I	**Sales**	MMusg	20	40	40	40	40	40	40	40	40	40
J	**Wet ethanol required**	MMusg	21	42.1	42.1	42.1	42.1	42.1	42.1	42.1	42.1	42.1
K	**Sales revenue**	MM$	18	33.2	34	34.8	35.6	36.8	38.4	39.6	41.2	40.8
L	**CBI value added requirement (35%)**	MM$	6.3	11.62	11.9	12.18	12.46	12.88	13.44	13.86	14.42	14.28
M	**Petrojam operating costs**											

1	Cash			MM$	3.3	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9
2	CBI qualifying			MM$	3.8	6.4	6.4	6.4	6.4	6.4	6.4	6.4	6.4	6.4
3	Remanining CBI requiremen			MM$	2.5	5.2	5.4	5.8	6.2	6.6	7	7.5	8	7.9
N	Adjusted for inflation		1	MM$	1.11	1.98	1.98	1.98	1.98	1.98	1.98	1.98	1.98	1.98
	and exchange rate		2	MM$	1.28	2.15	2.15	2.15	2.15	2.15	2.15	2.15	2.15	2.15
	of J$36=1$	9/8/93	3	MM$	0.84	1.74	1.81	1.95	2.08	2.21	2.35	2.52	2.68	2.65
	Configuration - I													
	Export to US Gulf coast under CBI assuming													
	wet ethanol is available from EEC													
O	**Alternative - 1**													
1	Supply under CBI based on EEC wet				**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	2001
	ethanol and sell off Petronol distillery													
					1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
2	Quantity ex - caribbean			MMusg	2.2	5	5.2	5.3	5.5	5.7	5.9	6.1	6.3	6.2
3	Quantity ex EEC			MMusg	18.8	37.1	36.9	36.8	36.6	36.4	36.2	36	35.8	35.8
4	Cash flow summary			MM$										
5	Inflow													
6	Sales revenue				18	33.2	34	34.8	35.6	36.8	38.4	39.6	41.2	40.8
7	Petronol sale				3									
8	Outflow													
9	EEC wet ethanol				10.15	19.29	19.56	19.50	19.76	20.02	20.27	20.52	20.76	20.76
10	Caribbean wet ethanol				2.44	5.15	5.51	5.78	6.16	6.61	7.08	7.56	8.06	7.87
11	Petrojam cash operating costs				1.11	1.98	1.98	1.98	1.98	1.98	1.98	1.98	1.98	1.98
12	Net cash flow				7.30	6.78	6.95	7.54	7.70	8.19	9.07	9.54	10.39	10.18
13	Discount factor		15%		0.87	0.76	0.66	0.57	0.50	0.43	0.38	0.33	0.28	0.25
14	PV				6.34	5.13	4.57	4.31	3.83	3.54	3.41	3.12	2.95	2.52
15	**NPV @**	15%		39.71										
P	**Alternative 2**													
1	Supply USGC under CBI using majority EEC wet ethanol													
	and the balance from the Petronol wet ethanol													
					1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
2	Quantity ex - petronol			MMusg	2	4.2	4.4	4.6	4.9	5.3	5.6	6	6.4	6.3
3	Quantity ex - EEC			MMusg	19.1	37.9	37.7	37.5	37.2	36.8	36.5	36	35.6	35.7
	Inflow													
4	Sales revenue			MM$	18	33.2	34	34.8	35.6	36.8	38.4	39.6	41.2	40.8
5	Outflow													
6	Petronol investment				4									
7	ECC wet ethanol				10.31	19.71	19.98	19.88	20.09	20.24	20.44	20.52	20.65	20.71
8	Petronol wet ethanol				0.94	1.97	2.07	2.16	2.30	2.49	2.63	2.82	3.01	2.96
9	Petrojam cash operating costs				1.11	1.98	1.98	1.98	1.98	1.98	1.98	1.98	1.98	1.98
10	Net cash flow				1.64	9.54	9.97	10.78	11.23	12.09	13.35	14.28	15.56	15.15
11	Discount factor		15%		0.87	0.76	0.66	0.57	0.50	0.43	0.38	0.33	0.28	0.25
12	PV				1.42	7.21	6.56	6.17	5.58	5.23	5.02	4.67	4.42	3.75
13	**NPV @**	15%		50.02										
Q	**Alternative 3**													
1	Supply USGC under CBI using maximum production capacity of the													
	Petronol for wet ethanol and balance from EEC													
					1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
2	Quantity ex - petronol			MMusg	15	15	15	15	15	15	15	15	15	15
3	Quantity ex - EEC			MMusg	6.2	26.11	26.11	26.11	26.11	26.11	26.11	26.11	26.11	26.11

	Inflow													
4	Sales revenue			MM$	18	33.2	34	34.8	35.6	36.8	38.4	39.6	41.2	40.8
5	Outflow													
6	Petronol investment				4									
7	ECC feedstock				3.35	13.58	13.84	13.84	14.10	14.36	14.62	14.88	15.14	15.14
8	Petronol feedstock				7.05	7.05	7.05	7.05	7.05	7.05	7.05	7.05	7.05	7.05
9	Petrojam cash operating costs				1.51	1.98	1.98	1.98	1.98	1.98	1.98	1.98	1.98	1.98
10	Net cash flow				2.09	10.59	11.13	11.93	12.47	13.41	14.75	15.69	17.03	16.63
11	Discount factor		15%		0.87	0.76	0.66	0.57	0.50	0.43	0.38	0.33	0.28	0.25
12	PV				1.82	8.01	7.32	6.82	6.20	5.80	5.54	5.13	4.84	4.11
13	**NPV @**	15%		55.59										
	Configuration II													
	Export to USGC under CBI assuming no supply is available from EEC													
R	**Alternative -1**													
1	Export under CBI using all wet ethanol from caribbean													
	belize based company and sell petronol													
	Cash flow summary			MM$	1	2	3	4	5	6	7	8	9	10
2	Inflow													
3	Sales revenue				18	33.2	34	34.8	35.6	36.8	38.4	39.6	41.2	40.8
4	Petronol sale				3									
5	Outflow													
6	Caribbean wet ethanol				23.31	43.36	44.63	45.89	47.15	48.84	50.52	52.20	53.89	53.47
7	Petrojam cash operating costs				1.11	1.98	1.98	1.98	1.98	1.98	1.98	1.98	1.98	1.98
8	Net cash flow				-3.42	-12.143	-12.606	-13.069	-13.53	-14	-14.1	-14.6	-14.7	-14.6
9	Discount factor		15%		0.87	0.76	0.66	0.57	0.50	0.43	0.38	0.33	0.28	0.25
10	PV				-2.97	-9.18	-8.29	-7.47	-6.73	-6.06	-5.30	-4.77	-4.17	-3.62
11	**NPV @**	15%		-58.56										
S	**Alternative - 2**													
1	Export under CBI by using maximum wet ethnol from Petronol													
	and the rest from caribbean													
2	Cash flow summary			MM$	1	2	3	4	5	6	7	8	9	10
3	Inflow													
4	Sales revenue				18	33.2	34	34.8	35.6	36.8	38.4	39.6	41.2	40.8
5	Outflow													
6	Petronol investment				4									
7	Petronol wet ethanol				7.04	7.04	7.04	7.04	7.04	7.04	7.04	7.04	7.04	7.04
8	Caribbean wet ethanol				6.69	27.85	28.66	29.47	30.28	31.37	32.45	33.53	34.61	34.34
9	Petrojam cash operating costs				1.51	1.98	1.98	1.98	1.98	1.98	1.98	1.98	1.98	1.98
10	Net cash flow				-1.24	-3.67	-3.68	-3.69	-3.70	-3.58	-3.06	-2.95	-2.43	-2.56
11	Discount factor		15%		0.87	0.76	0.66	0.57	0.50	0.43	0.38	0.33	0.28	0.25
12	PV				-1.08	-2.77	-2.42	-2.11	-1.84	-1.55	-1.15	-0.96	-0.69	-0.63
13	**NPV @**	15%		-15.20										
	Configuration III													
T	Supply to Jamaica gasohol blending progarm													
1	Total gasoline demand			MMBL	2.07	2.13	2.19	2.26	2.33	2.4	2.47	2.54	2.62	2.7
2	Ethanol for 100% gasohol			MMusg	8.69	8.95	9.21	9.49	9.78	10.07	10.37	10.68	11	11.33

U	**Alternative - 1**													
1	All wet ethanol obtained from Caribbean region													
					1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
2	Inflow													
3	Sales revenue				5.47	5.01	5.34	5.69	6.06	6.55	7.16	7.69	8.36	8.50
4	Outflow													
5	Caribbean wet ethanol				9.65	9.22	9.76	10.34	10.95	11.68	12.44	13.24	14.08	14.39
6	Petrojam cash operating costs				0.42	0.42	0.42	0.44	0.44	0.44	0.46	0.46	0.48	0.48
7	Net cash flow				-4.59	-4.63	-4.84	-5.09	-5.33	-5.58	-5.75	-6.01	-6.20	-6.37
8	Discount factor		15%		0.87	0.76	0.66	0.57	0.50	0.43	0.38	0.33	0.28	0.25
9	PV				-3.99	-3.50	-3.18	-2.91	-2.65	-2.41	-2.16	-1.97	-1.76	-1.57
10	**NPV @**	15%		-26.11										
U	**Alternative - 2 A**													
1	All wet ethanol obtained from the Petronol and petronol production													
	cost calculated using an exchange rate of J$ 22 = 1$													
					1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
2	Inflow													
3	Sales revenue				5.47	5.01	5.34	5.69	6.06	6.55	7.16	7.69	8.36	8.50
4	Outflow													
5	Petronol wet ethanol				6.60	6.80	7.00	7.21	7.43	7.65	7.88	8.12	8.36	8.61
6	Petrojam cash operating costs				0.42	0.42	0.42	0.44	0.44	0.44	0.46	0.46	0.48	0.48
7	Net cash flow				-1.55	-2.21	-2.08	-1.96	-1.81	-1.55	-1.19	-0.89	-0.48	-0.59
8	Discount factor		15%		0.87	0.76	0.66	0.57	0.50	0.43	0.38	0.33	0.28	0.25
9	PV				-1.35	-1.67	-1.37	-1.12	-0.90	-0.67	-0.45	-0.29	-0.14	-0.15
10	**NPV @**	15%		-8.09										
	NOTE:	In the above calculations revenue from fertilizer and the methane is not included.												
		They are the byproducts of the distillery for which cost of $ 4 million has been included.												
V	**Alternative - 2 B**													
1	All the wet ethanol obtained from petronol and production													
	cost of the Petronol wet ethanol calculated using J$ 36 = 1$													
					1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
2	Inflow													
3	Sales revenue				5.47	5.01	5.34	5.69	6.06	6.55	7.16	7.69	8.36	8.50
3	Outflow													
4	Petronol wet ethanol				4.08	4.21	4.33	4.46	4.60	4.73	4.87	5.02	5.17	5.33
5	Petrojam cash operating costs				0.42	0.42	0.42	0.44	0.44	0.44	0.46	0.46	0.48	0.48
6	Net cash flow				0.97	0.39	0.59	0.79	1.03	1.37	1.82	2.21	2.71	2.69
7	Discount factor		15%		0.87	0.76	0.66	0.57	0.50	0.43	0.38	0.33	0.28	0.25
8	PV				0.84	0.29	0.39	0.45	0.51	0.59	0.68	0.72	0.77	0.67
9	**NPV @**	15%		5.93										
W	**Exchange rate simulation to obtain zero NPV**													
1	Exchange rate		US$ 1=	JS$	29.1	29.1	29.1	29.1	29.1	29.1	29.1	29.1	29.1	29.1
2	Petronol wet ethanol				5.05	5.20	5.36	5.52	5.69	5.86	6.03	6.21	6.40	6.59
3	Petrojam cash operating costs				0.52	0.52	0.52	0.54	0.54	0.54	0.57	0.57	0.59	0.59
4	Total costs				5.57	5.72	5.87	6.06	6.23	6.40	6.60	6.78	6.99	7.18
5	Net cash flow				-0.10	-0.71	-0.53	-0.37	-0.17	0.15	0.56	0.91	1.37	1.32
6	Discount factor		15%		0.87	0.76	0.66	0.57	0.50	0.43	0.38	0.33	0.28	0.25
7	discounted cash flow				-0.08	-0.54	-0.35	-0.21	-0.08	0.06	0.21	0.30	0.39	0.33
8	**NPV**			0.02										

	Worksheet 3 A	**COGENERATION PLANT**					
		At the Bernard Lodge factory using BIG/ ISTIG technology					
	Commercial Appraisal: Return on Investment (assets) before taxes.						
A.	**Parameters:**	For explanation of parameters and thier formula, see also end of worksheet					
				Formula or assumtion			
1	Exchange rate (9/8/1993) US$ 1= JS$	36		Baybank (8/13/93)			
2	Lowest price of electricity in cents / KWh	2		Assumption			
3	Highest price of electricity in cents / kWh	5		Assumption			
4	Bagasse in $/GJ (includes processing)	$0.23		((1.25*5.49)*120/100)/36			
5	Barbajo processing cost in $ / GJ	$0.07		((0.4*5.49)*120/100)/36			
6	Barbajo collection cost $ / GJ	$0.19		((1.05*5.49)*120/100)/36			
7	Energy content in bagasse per ton	8.96	GJ	(Energy content - 2690 MJ per 283-300 kg bagasse - (6) Goldemberg, Monaco, Macedo 1993).			
8	Energy content in barbojo per ton	19.22	GJ	(Energy content - 3460 MJ per 180 kg of barbojo - (6) Godemberg, Monaco, Macedo 1993)			
9	Price of steam in kg / tc			Unknown			
10	Net electrical output (MW - power mode)	111.2		(15)(Ogden, Fulmer 1990)			
11	Net electrical output (MW- in cogeneration mode)	97.4		(15)(Ogden, Fulmer 1990)			
12	Efficiency (in power mode)	42.90%		(15)(Ogden, Fulmer 1990)			
13	Efficiency (in cogeneration mode)	37.90%		(15)(Ogden, Fulmer 1990)			
14	Process steam (in power mode)	0					
15	Process steam kg / tc (cogeneration mode)	235		(15)(Ogden, Fulmer 1990)			
16	Electricity for a sugar factory or distillery (in power mode)	339		(15)(Ogden, Fulmer 1990)			
17	Electricity for a sugar factory or distillery (in cogeneration mode)	300		(15)(Ogden, Fulmer 1990)			
B.	**Investment**						
1	Installed capital cost for General Electric Co. BIG / ISTIG cogeneration system - capital cost for "LM - 8000" at the rate of $ 870 / kW	$96,744,000		(1) page 755 (Williams, Larson 1993)			
2	Working capital	$4,056,667		Assumption			
3	Total	$100,800,667					
3	**Equity**	$20,800,667		Assumtion			
4	**Loan**	$80,000,000		Assumtion			
C.	**Revenues (without taxes)**						
1	Revenue @ 2 cents / kWh in cogeneration mode during the milling season	$6,218,016			133	days	(97.4*1000*24*133 days*2 cents)/100
2	Revenue @ 2 cents / kWh in power mode during the off - season	$12,383,232	18.59	Total	232	days	(97.4*1000*24*232 days*2 cents)/100
3	Revenue @ 3 cents / kWh - cogeneration	$9,327,024			133	dyas	(97.4*1000*24*133 days*3 cents)/100

4	Revenue @ 3 cents / kWh - power mode	$18,574,848	27.89	Total	232	days	(97.4*1000*24*232 days*3 cents)/100											
5	Revenue @ 4 cents / kWh - cogeneration	$12,436,032			133	dyas	(97.4*1000*24*133 days*4 cents)/100											
6	Revenue @ 4 cents / kWh - power mode	$24,766,464	37.19	Total	232	days	(97.4*1000*24*232 days*4 cents)/100											
7	Revenue @ 5 cents / kWh - cogeneration	$15,545,040			133	dyas	(97.4*1000*24*133 days*5 cents)/100											
8	Revenue @ 5 cents / kWh - power mode	$30,958,080	46.49	Total	232	days	(97.4*1000*24*232 days*5 cents)/100											
5	Process steam output @ 235 kg / tc						Revenue not considered.											
D.	**Annual costs**																	
	Busbar costs for BIG / ISTIG																	
1	Fuel - Bagasse during the season	1638802	GJ	133	days	(8.96*182902)												
2	Annual processing cost @ $ 0.23 / GJ	$374,876																
3	Fuel - Barbojo during the off-season	6174867	GJ	232	days	(321274*19.22)												
4	Annual barbojo processing cost @ $ 0.07/GJ	$452,000																
5	Annual barbojo collection costs @ $ 0.19/GJ	$1,186,501																
6	Fixed - Labor (7 operator @ $ 5 per hour)	$72,800				(1) page 748 (Williams, Larson 1993)												
7	Fixed - Maintenance (labor 40%)	$140,080				(1) page 748 (Williams, Larson 1993)												
8	- Maintenance (material 60%)	$1,050,600				(1) page 748 (Williams, Larson 1993)												
9	Fixed - Administration	$379,044				(1) page 748 (Williams, Larson 1993)												
10	Variable - water requirement	$253,269				(1) page 748 (Williams, Larson 1993)												
11	Variable - solid disposal	$574,726				(1) page 748 (Williams, Larson 1993)												
12	Total	$4,483,896																
E.	**Salvage value**																	
	Depriciation					Not known and considered.												
F.	**Cash flow (2 cents / kWhr)**	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
	All figures are in MM = thousands																	
	Cash inflow																	
1	Revenue from electricity				18.59	18.59	18.59	18.59	18.59	18.59	18.59	18.59	18.59	18.59	18.59	18.59	18.59	
2	Credit revenue from process steam																	
3	Liquidation of plant																	24.19
	Total cash inflows	0	0	0	18.59	18.59	18.59	18.59	18.59	18.59	18.59	18.59	18.59	18.59	18.59	18.59	18.59	
	Cash outflows																	
1	Investments	10	70	20.79														
2	labor cost			0.72	0.72	0.72	0.72	0.72	0.72	0.72	0.72	0.72	0.72	0.72	0.72	0.72	0.72	
	Maintenance (labor)				0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	
	Maintenance (materials)				1.05	1.05	1.05	1.05	1.05	1.05	1.05	1.05	1.05	1.05	1.05	1.05	1.05	
3	Annual costs - variable				0.82	0.82	0.82	0.82	0.82	0.82	0.82	0.82	0.82	0.82	0.82	0.82	0.82	
4	Fuel cost - bagasse (processing)				0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	
5	Fuel cost - barbojo (processing)				0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45	
6	Fuel cost - barbojo (collection)				1.18	1.18	1.18	1.18	1.18	1.18	1.18	1.18	1.18	1.18	1.18	1.18	1.18	
	Total cash outflow	10	70	21.51	4.73	4.73	4.73	4.73	4.73	4.73	4.73	4.73	4.73	4.73	4.73	4.73	4.73	
	Net cash outflow	-10	-70	-21.51	13.86	13.86	13.86	13.86	13.86	13.86	13.86	13.86	13.86	13.86	13.86	13.86	13.86	24.19
G.	**Net present value**																	

	1. At 8%																	
	a) discount factor	1.00	0.93	0.86	0.79	0.74	0.68	0.63	0.58	0.54	0.50	0.46	0.43	0.40	0.37	0.34	0.32	0.29
	b) present value	-10	-64.81	-18.44	11	10.19	9.433	8.734	8.087	7.488	6.933	6.42	5.944	5.504	5.096	4.719	4.369	7.06
	c) NPV	7.72																
	1. At 12%																	
	a) discount factor	1.00	0.89	0.80	0.71	0.64	0.57	0.51	0.45	0.40	0.36	0.32	0.29	0.26	0.23	0.20	0.18	0.16
	b) present value	-10.00	-62.50	-17.15	9.87	8.81	7.86	7.02	6.27	5.60	5.00	4.46	3.98	3.56	3.18	2.84	2.53	3.95
	c) NPV	-18.67																
	3. At 15%																	
	a) discount factor	1.00	0.87	0.76	0.66	0.57	0.50	0.43	0.38	0.33	0.28	0.25	0.21	0.19	0.16	0.14	0.12	0.11
	b) present value	-10.00	-60.87	-16.26	9.11	7.92	6.89	5.99	5.21	4.53	3.94	3.43	2.98	2.59	2.25	1.96	1.70	2.58
	c) NPV	-28.62																
	4. At 40%																	
	a) discount factor	1.00	0.71	0.51	0.364	0.26	0.186	0.133	0.095	0.068	0.048	0.035	0.025	0.018	0.013	0.009	0.006	0.00
	b) present value	-10.00	-50.00	-10.97	5.05	3.61	2.58	1.84	1.31	0.94	0.67	0.48	0.34	0.24	0.17	0.12	0.09	0.11
	c) NPV	-53.52																
H.	**Cash flow (3 cents / kWhr)**	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
	All figures are in MM = thousands																	
	Cash inflow																	
1	Revenue from electricity				27.89	27.89	27.89	27.89	27.89	27.89	27.89	27.89	27.89	27.89	27.89	27.89	27.89	
2	Credit revenue from process steam																	24.19
3	Liquidation of plant																	
	Total cash inflows	0	0	0	27.89	27.89	27.89	27.89	27.89	27.89	27.89	27.89	27.89	27.89	27.89	27.89	27.89	
	Cash outflows																	
1	Investments	10	70	20.79														
2	labor cost			0.72	0.72	0.72	0.72	0.72	0.72	0.72	0.72	0.72	0.72	0.72	0.72	0.72	0.72	
	Maintenance (labor)				0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	
	Maintenance (materials)				1.05	1.05	1.05	1.05	1.05	1.05	1.05	1.05	1.05	1.05	1.05	1.05	1.05	
3	Annual costs - variable				0.82	0.82	0.82	0.82	0.82	0.82	0.82	0.82	0.82	0.82	0.82	0.82	0.82	
4	Fuel cost - bagasse (processing)				0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	
5	Fuel cost - barbojo (processing)				0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45	
6	Fuel cost - barbojo (collection)				1.18	1.18	1.18	1.18	1.18	1.18	1.18	1.18	1.18	1.18	1.18	1.18	1.18	
	Total cash outflow	10	70	21.51	4.73	4.73	4.73	4.73	4.73	4.73	4.73	4.73	4.73	4.73	4.73	4.73	4.73	
	Net cash outflow	-10	-70	-21.51	23.16	23.16	23.16	23.16	23.16	23.16	23.16	23.16	23.16	23.16	23.16	23.16	23.16	24.2
I.	**Net present value**																	
	1. At 8%																	
	a) discount factor	1.00	0.93	0.86	0.79	0.74	0.68	0.63	0.58	0.54	0.50	0.46	0.43	0.40	0.37	0.34	0.32	0.29
	b) present value	-10	-64.81	-18.44	18.39	17.02	15.76	14.59	13.51	12.51	11.59	10.73	9.93	9.20	8.52	7.89	7.30	7.06
	c) NPV	63.68																
	1. At 12%																	
	a) discount factor	1.00	0.89	0.80	0.71	0.64	0.57	0.51	0.45	0.40	0.36	0.32	0.29	0.26	0.23	0.20	0.18	0.16
	b) present value	-10.00	-62.50	-17.15	16.48	14.72	13.14	11.73	10.48	9.35	8.35	7.46	6.66	5.94	5.31	4.74	4.23	3.95
	c) NPV	28.95																

	3. At 15%																	
	a) discount factor	1.00	0.87	0.76	0.66	0.57	0.50	0.43	0.38	0.33	0.28	0.25	0.21	0.19	0.16	0.14	0.12	0.11
	b) present value	-10.00	-60.87	-16.26	15.23	13.24	11.51	10.01	8.71	7.57	6.58	5.72	4.98	4.33	3.76	3.27	2.85	2.59
	c) NPV	10.64																
	4. At 40%																	
	a) discount factor	1.00	0.71	0.51	0.36	0.26	0.19	0.13	0.09	0.07	0.05	0.03	0.02	0.02	0.01	0.01	0.01	0.00
	b) present value	-10.00	-50.00	-10.97	8.44	6.03	4.31	3.08	2.20	1.57	1.12	0.80	0.57	0.41	0.29	0.21	0.15	0.11
	c) NPV	-41.81																
J.	**Cash flow (4 cents / kWhr)**	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
	All figures are in MM = thousands																	
	Cash inflow																	
1	Revenue from electricity				37.19	37.19	37.19	37.19	37.19	37.19	37.19	37.19	37.19	37.19	37.19	37.19	37.19	
2	Credit revenue from process steam																	24.19
3	Liquidation of plant																	
	Total cash inflows	0	0	0	37.19	37.19	37.19	37.19	37.19	37.19	37.19	37.19	37.19	37.19	37.19	37.19	37.19	
	Cash outflows																	
1	Investments	10	70	20.79														
2	labor cost			0.72	0.72	0.72	0.72	0.72	0.72	0.72	0.72	0.72	0.72	0.72	0.72	0.72	0.72	
	Maintenance (labor)				0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	
	Maintenance (materials)				1.05	1.05	1.05	1.05	1.05	1.05	1.05	1.05	1.05	1.05	1.05	1.05	1.05	
3	Annual costs - variable				0.82	0.82	0.82	0.82	0.82	0.82	0.82	0.82	0.82	0.82	0.82	0.82	0.82	
4	Fuel cost - bagasse (processing)				0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	
5	Fuel cost - barbojo (processing)				0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45	
6	Fuel cost - barbojo (collection)				1.18	1.18	1.18	1.18	1.18	1.18	1.18	1.18	1.18	1.18	1.18	1.18	1.18	
	Total cash outflow	10	70	21.51	4.73	4.73	4.73	4.73	4.73	4.73	4.73	4.73	4.73	4.73	4.73	4.73	4.73	
	Net cash outflow	-10	-70	-21.51	32.46	32.46	32.46	32.46	32.46	32.46	32.46	32.46	32.46	32.46	32.46	32.46	32.46	24.2
K.	**Net present value**																	
	1. At 8%																	
	a) discount factor	1.00	0.93	0.86	0.79	0.74	0.68	0.63	0.58	0.54	0.50	0.46	0.43	0.40	0.37	0.34	0.32	0.29
	b) present value	-10	-64.81	-18.44	25.77	23.86	22.09	20.46	18.94	17.54	16.24	15.04	13.92	12.89	11.94	11.05	10.23	7.06
	c) NPV	126.70																
	1. At 12%																	
	a) discount factor	1.00	0.89	0.80	0.71	0.64	0.57	0.51	0.45	0.40	0.36	0.32	0.29	0.26	0.23	0.20	0.18	0.16
	b) present value	-10.00	-62.50	-17.15	23.10	20.63	18.42	16.45	14.68	13.11	11.71	10.45	9.33	8.33	7.44	6.64	5.93	3.95
	c) NPV	76.57																
	3. At 15%																	
	a) discount factor	1.00	0.87	0.76	0.66	0.57	0.50	0.43	0.38	0.33	0.28	0.25	0.21	0.19	0.16	0.14	0.12	0.11
	b) present value	-10.00	-60.87	-16.26	21.34	18.56	16.14	14.03	12.20	10.61	9.23	8.02	6.98	6.07	5.28	4.59	3.99	2.59
	c) NPV	49.90																
	4. At 40%																	
	a) discount factor	1.00	0.71	0.51	0.36	0.26	0.19	0.13	0.09	0.07	0.05	0.03	0.02	0.02	0.01	0.01	0.01	0.00
	b) present value	-10.00	-50.00	-10.97	11.83	8.45	6.04	4.31	3.08	2.20	1.57	1.12	0.80	0.57	0.41	0.29	0.21	0.11
	c) NPV	-30.09																

L.	**Cash flow (5 cents / kWhr)**	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
	All figures are in MM = thousands																	
	Cash inflow																	
1	Revenue from electricity				37.19	37.19	37.19	37.19	37.19	37.19	37.19	37.19	37.19	37.19	37.19	37.19	37.19	
2	Credit revenue from process steam																	24.19
3	Liquidation of plant																	
	Total cash inflows	0	0	0	46.49	46.49	46.49	46.49	46.49	46.49	46.49	46.49	46.49	46.49	46.49	46.49	46.49	
	Cash outflows																	
1	Investments	10	70	20.79														
2	labor cost			0.72	0.72	0.72	0.72	0.72	0.72	0.72	0.72	0.72	0.72	0.72	0.72	0.72	0.72	
	Maintenance (labor)				0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	
	Maintenance (materials)				1.05	1.05	1.05	1.05	1.05	1.05	1.05	1.05	1.05	1.05	1.05	1.05	1.05	
3	Annual costs - variable				0.82	0.82	0.82	0.82	0.82	0.82	0.82	0.82	0.82	0.82	0.82	0.82	0.82	
4	Fuel cost - bagasse (processing)				0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	
5	Fuel cost - barbojo (processing)				0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45	
6	Fuel cost - barbojo (collection)				1.18	1.18	1.18	1.18	1.18	1.18	1.18	1.18	1.18	1.18	1.18	1.18	1.18	
	Total cash outflow	10	70	21.51	4.73	4.73	4.73	4.73	4.73	4.73	4.73	4.73	4.73	4.73	4.73	4.73	4.73	
	Net cash outflow	-10	-70	-21.51	41.76	41.76	41.76	41.76	41.76	41.76	41.76	41.76	41.76	41.76	41.76	41.76	41.76	24.2
M.	**Net present value**																	
	1. At 8%																	
	a) discount factor	1.00	0.93	0.86	0.79	0.74	0.68	0.63	0.58	0.54	0.50	0.46	0.43	0.40	0.37	0.34	0.32	0.29
	b) present value	-10	-64.81	-18.44	33.15	30.69	28.42	26.32	24.37	22.56	20.89	19.34	17.91	16.58	15.36	14.22	13.16	7.06
	c) NPV	189.72																
	1. At 12%																	
	a) discount factor	1.00	0.89	0.80	0.71	0.64	0.57	0.51	0.45	0.40	0.36	0.32	0.29	0.26	0.23	0.20	0.18	0.16
	b) present value	-10.00	-62.50	-17.15	29.72	26.54	23.70	21.16	18.89	16.87	15.06	13.45	12.01	10.72	9.57	8.54	7.63	3.95
	c) NPV	124.20																
	3. At 15%																	
	a) discount factor .	1.00	0.87	0.76	0.66	0.57	0.50	0.43	0.38	0.33	0.28	0.25	0.21	0.19	0.16	0.14	0.12	0.11
	b) present value	-10.00	-60.87	-16.26	27.46	23.88	20.76	18.05	15.70	13.65	11.87	10.32	8.98	7.81	6.79	5.90	5.13	2.59
	c) NPV	89.16																
	4. At 40%																	
	a) discount factor	1.00	0.71	0.51	0.36	0.26	0.19	0.13	0.09	0.07	0.05	0.03	0.02	0.02	0.01	0.01	0.01	0.00
	b) present value	-10.00	-50.00	-10.97	15.22	10.87	7.76	5.55	3.96	2.83	2.02	1.44	1.03	0.74	0.53	0.38	0.27	0.11
	c) NPV	-18.38																
	Worksheet 3 B																	
	Commercial appraisal: Return on equity																	
		0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	
A.	**Profit after taxes**																	
	1. Net cash flow, worksheet 1	-10.00	-70.00	-21.51	13.86	13.86	13.86	13.86	13.86	13.86	13.86	13.86	13.86	13.86	13.86	13.86	13.86	
	line																	
	2. Add back investments	10.00	70.00	21.51														
	3. Subtract:																	
	a) depriciation				3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	

	b) interest				5.13	4.85	4.57	4.26	3.94	3.60	3.23	2.85	2.44	2.01	1.55	1.06	0.55
	c) salvage value																24.19
	4. Profit before taxes	0.00	0.00	0.00	5.73	6.01	6.29	6.60	6.92	7.26	7.63	8.01	8.42	8.85	9.31	9.80	-13.88
	5. Company taxes				-2.01	-2.10	-2.20	-2.31	-2.42	-2.54	-2.67	-2.80	-2.95	-3.10	-3.26	-3.43	4.86
	6. Profit after taxes				7.74	8.11	8.50	8.91	9.34	9.81	10.30	10.82	11.37	11.95	12.57	13.23	-18.73
B.	**Cash flow to equity**																
	1. Investment	-100.74															
	2. Proceeds of loan	80.00															
	3. Repayment of principal				-6.57	-6.57	-6.57	-6.57	-6.57	-6.57	-6.57	-6.57	-6.57	-6.57	-6.57	-6.57	-6.57
	4. Profit after taxes				7.74	8.11	8.50	8.91	9.34	9.81	10.30	10.82	11.37	11.95	12.57	13.23	-18.73
	5. Add back :																
	a) depriciation				3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00
	b) salvage value																24.19
	6. Net cash flow to equity	-20.74			4.17	4.54	4.93	5.34	5.77	6.24	6.73	7.25	7.80	8.38	9.00	9.66	-22.30
C.	**Net present value**																
	1. At 15%																
	a) discount factor	1.00	0.87	0.76	0.66	0.57	0.50	0.43	0.38	0.33	0.28	0.25	0.21	0.19	0.16	0.14	0.12
	b) present value	-20.74	0.00	0.00	2.74	2.59	2.45	2.31	2.17	2.04	1.91	1.79	1.68	1.57	1.46	1.37	-2.74
	c) NPV	0.60															
	Loan payment worked out as follows:				13	12	11	10	9	8	7	6	5	4	3	2	1
	Jenkins	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	Capital cost borrowed ($80,000,000)	10.00		70.00													
4	Interest rate (6%)																
5	Outstanding balances at the begining of year		10.00	80.60	85.44	80.91	76.11	71.03	65.64	59.93	53.87	47.45	40.65	33.44	25.79	17.69	9.10
6	Interest accruing during the year		10.60	85.44	90.56	85.77	80.68	75.29	69.58	63.52	57.10	50.30	43.09	35.44	27.34	18.75	9.64
8	Interest accumulation		0.60	4.84	5.13	4.85	4.57	4.26	3.94	3.60	3.23	2.85	2.44	2.01	1.55	1.06	0.55
9	Annual repayment		0.00	0.00	9.65	9.65	9.65	9.65	9.65	9.65	9.65	9.65	9.65	9.65	9.65	9.65	9.65
	interest		0.00	0.00	5.13	4.85	4.57	4.26	3.94	3.60	3.23	2.85	2.44	2.01	1.55	1.06	0.55
	principal		0.00	0.00	4.53	4.80	5.08	5.39	5.71	6.06	6.42	6.80	7.21	7.65	8.10	8.59	9.11
10	Balance outstanding at the end of year	10.00	10.60	85.44	80.91	76.11	71.03	65.64	59.93	53.87	47.45	40.65	33.44	25.79	17.69	9.10	-0.01
	Loan payment worked out as follows:																
	Ghana																
	Loan proceeds	10.00	0.00	70.00	0.00												
	Repayment of principal	0.00	0.00	0.00	6.57	6.57	6.57	6.57	6.57	6.57	6.57	6.57	6.57	6.57	6.57	6.57	1.76
	Balance outstanding at the end of year	10.00	10.00	80.60	74.03	67.46	60.89	54.32	47.75	41.18	34.61	28.04	21.47	14.90	8.33	1.76	0.00
	Interest at 6% on previous year's balance	0.00	0.60	4.84	4.44	4.05	3.65	3.26	2.87	2.47	2.08	1.68	1.29	0.89	0.50	0.11	0.00
	Worksheet 3 C																
	Social Appraisal																

A.	**Investment**																	
	1. Imported equipment																	
	a) c.i.f. value		76.34															
	b) duty at 5%		3.82															
	2. Site preparation																	
	a) materials of which																	
	i) import content	0																
	ii) duty	0																
	iii) domestic materials	8.32																
	b) labor	4.50																
	3. Inventory of supplies																	
	a) c.i.f. value			2.50														
	b) duty at 5%			0.13														
	4. Total investment	12.82	80.16	2.63														
B.	**Benefits**																	
1	Reduced import of oil for electricity				12.78	12.78	12.78	12.78	12.78	12.78	12.78	12.78	12.78	12.78	12.78	12.78	12.78	
2	Reduced cost of pollution treatment				19.12													
3	Reduced transmission cost																	
C	**Annual costs**																	
1	labor cost			0.72	0.72	0.72	0.72	0.72	0.72	0.72	0.72	0.72	0.72	0.72	0.72	0.72	0.72	
2	Maintenance (labor)				0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	
3	Annual costs - variable				0.82	0.82	0.82	0.82	0.82	0.82	0.82	0.82	0.82	0.82	0.82	0.82	0.82	
4	Fuel cost - bagasse (processing)				0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	
5	Fuel cost - barbojo (processing)				0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45	
6	Fuel cost -barbojo collection				1.18	1.18	1.18	1.18	1.18	1.18	1.18	1.18	1.18	1.18	1.18	1.18	1.18	
7	Imported materials																	
	a) c. i. f. value				1.05	1.05	1.05	1.05	1.05	1.05	1.05	1.05	1.05	1.05	1.05	1.05	1.05	
	b) duty at 5%				0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	
8	Transportation																	
	a) import content				0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	
	b) Local content				0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	
9	Total annual costs				5.63	5.63	5.63	5.63	5.63	5.63	5.63	5.63	5.63	5.63	5.63	5.63	5.63	
D	**Salvage value**																	
	Total salvage value																	24.2
E	**External costs**																	
	(Social amenities)																	
	1. Full cost of housing				1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	
	(30% of basic wage)																	
	2. Less: Rent paid by the workers				0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	
	(15% of basic wage)																	
	3. Net social cost				0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	

F.	**Net cash flow**																	
	1. Investments	13.00	80.00	3.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
	2. Benefits	0.00	0.00	0.00	31.80	12.78	12.78	12.78	12.78	12.78	12.78	12.78	12.78	12.78	12.78	12.78	12.78	
	3. Annual costs	0.00	0.00	0.00	5.63	5.63	5.63	5.63	5.63	5.63	5.63	5.63	5.63	5.63	5.63	5.63	5.63	
	4. Salvage value	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	24.19
	5. External costs	0.00	0.00	0.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	
	6. Net cash flow	13.00	80.00	3.00	25.17	6.15	6.15	6.15	6.15	6.15	6.15	6.15	6.15	6.15	6.15	6.15	6.15	24.19
G.	**Net present value**																	
	1. At 8%																	
	a) discount factor	1.00	0.93	0.86	0.79	0.74	0.68	0.63	0.58	0.54	0.50	0.46	0.43	0.40	0.37	0.34	0.32	0.29
	b) present value	13.00	74.07	2.57	19.98	4.52	4.19	3.88	3.59	3.32	3.08	2.85	2.64	2.44	2.26	2.09	1.94	7.06
	c) NPV	153.48																
	2. At 12%																	
	a) discount factor	1.00	0.89	0.80	0.71	0.64	0.57	0.51	0.45	0.40	0.36	0.32	0.29	0.26	0.23	0.20	0.18	0.16
	b) present value	13.00	71.43	2.39	17.92	3.91	3.49	3.12	2.78	2.48	2.22	1.98	1.77	1.58	1.41	1.26	1.12	3.95
	c) NPV	135.80																
	3. At 15%																	
	a) discount factor	1.00	0.87	0.76	0.66	0.57	0.50	0.43	0.38	0.33	0.28	0.25	0.21	0.19	0.16	0.14	0.12	0.11
	b) present value	13.00	69.57	2.27	16.55	3.52	3.06	2.66	2.31	2.01	1.75	1.52	1.32	1.15	1.00	0.87	0.76	2.59
	c) NPV	125.89																
	4. At 40%																	
	a) discount factor	1.00	0.71	0.51	0.36	0.26	0.19	0.13	0.09	0.07	0.05	0.03	0.02	0.02	0.01	0.01	0.01	0.00
	b) present value	13.00	57.14	1.53	9.17	1.60	1.14	0.82	0.58	0.42	0.30	0.21	0.15	0.11	0.08	0.06	0.04	0.11
	c) NPV	86.46																
	Source of information:																	
A 4	Based on the assumption in (15) (Ogden J., Fulmer M.1990) Table 18 Bagasse briquetting cost \$ 1.25/GJ (1987). 1993 cost = \$ 1.25* J\$ 5.49 exchange rate in 1987 * 120% infla																	
	and the whole divided by the current exchange rate. ((1.25*5.49*120/100))/36																	
A 5	Based on the assumption in (15) (Ogden J., Fulmer M.1990) Table 18 Barbojo processing cost \$ 0.40/GJ (1987) 1993 cost = \$ 0.4* J\$ 5.49 exchange rate in 1987 * 120% inflat																	
	and the whole divided by the current exchange rate. ((0.4*5.49*120/100))/36																	
A 6	Based on the assumption in (15) (Ogden J., Fulmer M.1990) Table 18 Barbojo collection cost \$ 1.05/GJ (1987) 1993 cost = \$ 1.05* J\$ 5.49 exchange rate in 1987 * 120% inflat																	
	and the whole divided by the current exchange rate. ((1.05*5.49*120/100))/36																	
A 7	Based on the assumption - Table 5 Page 319, (16) (Ogden J., Williams R., Fulmer M. 1990) that BIG/ISTIG use briquetted bagasse with higher heating value of 16166 kJ/kg.																	

	Worksheet 4	PETRONOL OPERATIONS (wet ethanol)	
		At the Bernard Lodge sugar factory	
	Commercial Appraisal: Return on investment (Assets) before income taxes		
A.	**Parameters:**		
1	Exchange rate (9/8/1993) US$ 1= JS$	36	
2	A - molasses kg/ton of cane	55	
3	Sugar kg/tc - Jamaican productivity (1991)	86	
4	Sugar cane/sugar ratio	11.51	
5	Production of (high biochemical oxygen	14	
	demand) stillage is equivalent to 14 litres per		
	per litre of ethanol produced		
6	Equivalent usgal per usgal of ethanol	3.70	
7	Fertilizer unit value for credit in cents/litre	0.20	
8	Equivalent value in cents/usg	0.74	
9	Price of hydrous ethanol = EEC cost of impor	$0.54	$/usg
10	Price of hydrous ethanol = EEC cost of impor	$0.14	$/litre
B.	**Investment**		
1	Innitial investment (1988)	$4,735,883	
2	Stillage treatment plant	$4,000,000	
3	Depriciated value (1992)	$3,000,000	
C.	**Revenues**		
1	Sale of sugar		
	a) production in tons	40000	
	b) value @ $ 604 (subsidized qouta pric	$24,160,000	
	c) less duty or sales tax @ 5%	$1,208,000	
	d) net revenue	$22,952,000	
2	Shadow price of sugar		
	or e) value @ $266 (world market price)	$10,640,000	
	f) less duty or sales tax	$532,000	
	g) net revenue	$10,108,000	
3	Export of molasses (opportunity cost)		
	a) production in tons	25322	
	b) value @ $ 80 per ton	$2,025,760	
	c) Less duty or sales tax @ 5%	$101,288	
	d) net revenue	$1,924,472	
4	Export or sale of ethanol to Petrojam		
	a) production in US gallons (usgal)	15000000	

	b) value @ $ 0.54/usg = EEC feedstock	$8,100,000																
	c) Less duty or sales tax @ 5%	$405,000																
	d) net revenue	$7,695,000																
5	Sale of fertilizer																	
	a) production in (usgal)	55477769																
	b) value @ 0.75 cents/ usgal	$416,083																
	c) Less duty or sales tax @ 5%	$20,804																
	d) net revenue	$395,279																
6	Sale of Bagasse																	
	a) production in tons (1779159 GJ)	184178																
	b) Value @ $ 0.15 / GJ	$266,874																
	c) Less duty or sales tax 5%	$13,344																
	d) net revenue	$253,530																
7	Sale of Barbojo from distillery plantation																	
	a) production in tons (4443810 GJ)	321274																
	b) Value @ $ 0.19 / GJ	$844,324																
	c) Less duty or sales tax @ 5%	$42,216																
	d) net revenue	$802,108																
C.	**Annual costs**																	
1	Fixed in (JS$8=US$) 1990-1991	$200,000																
2	Fixed (JS$22=US$) adjusted for 1992 inflation	$109,818																
3	Fixed (JS$36=US$) adjusted for inflation	$36,850																
4	Variable in US$ / usg (JS$8=US$) 1990-1991	$1.39																
5	Variable(JS$22=US$) adjusted (1992) inflatior	$0.76																
6	Variable(JS$36=US$) adjusted for inflation	$0.47																
D.	**Salvage value**																	
	Total salvage value (World Bank report)	$3,000,000																
E.	Cashflow (no credit for barbojo-bagasse)	Years 0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
	All figures are in MM = thousands																	
1	**Quantities**																	
2	Ethanol @ 90% capacity		14.00	14.00	14.00	14.00	14.00	14.00	14.00	14.00	14.00	14.00	14.00	14.00	14.00	14.00	14.00	
3	Fertilizer @ 3.7 usg per usg of ethanol		51.78	51.78	51.78	51.78	51.78	51.78	51.78	51.78	51.78	51.78	51.78	51.78	51.78	51.78	51.78	
4	Bagsse @ 300Kg/tc																	
5	Barbojo 330 kg/tc																	
6	**Cash Inflows**																	
7	Revenue from hydrous ethanol @ $ 0.54/usg	0.00	7.56	7.56	7.56	7.56	7.56	7.56	7.56	7.56	7.56	7.56	7.56	7.56	7.56	7.56	7.56	
8	Credit revenue from fertilizer sale	0.00	0.39	0.39	0.39	0.39	0.39	0.39	0.39	0.39	0.39	0.39	0.39	0.39	0.39	0.39	0.39	
9	Liquidation of plant																	3.00
10	Credit value of Barbojo	0.00																
11	Credit value of bagasse	0.00																
12	**Total cash inflows**	0.00	7.95	7.95	7.95	7.95	7.95	7.95	7.95	7.95	7.95	7.95	7.95	7.95	7.95	7.95	7.95	

13	**Cash outflows**																
14	Investments	8.70															
15	Annual costs - fixed		0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	
16	Annual costs - variable		6.58	6.58	6.58	6.58	6.58	6.58	6.58	6.58	6.58	6.58	6.58	6.58	6.58	6.58	6.58	
17	**Total cash outflow**	8.70	6.61	6.61	6.61	6.61	6.61	6.61	6.61	6.61	6.61	6.61	6.61	6.61	6.61	6.61	6.61	
18	**Net cash outflow**	-8.70	1.34	1.34	1.34	1.34	1.34	1.34	1.34	1.34	1.34	1.34	1.34	1.34	1.34	1.34	1.34	3.00
F.	**Net present value**																
	1. At 8%																
	a) discount factor	1.00	0.93	0.86	0.79	0.74	0.68	0.63	0.58	0.54	0.50	0.46	0.43	0.40	0.37	0.34	0.32	0.29
	b) present value	-8.70	1.24	1.15	1.06	0.98	0.91	0.84	0.78	0.72	0.67	0.62	0.57	0.53	0.49	0.46	0.42	0.88
	c) NPV	3.63																
	2. At 12%																
	a) discount factor	1.00	0.89	0.80	0.71	0.64	0.57	0.51	0.45	0.40	0.36	0.32	0.29	0.26	0.23	0.20	0.18	0.16
	b) present value	-8.70	1.19	1.07	0.95	0.85	0.76	0.68	0.61	0.54	0.48	0.43	0.38	0.34	0.31	0.27	0.24	0.49
	c) NPV	0.90																
	3. At 15%																
	a) discount factor	1.00	0.88	0.77	0.68	0.60	0.53	0.46	0.41	0.36	0.31	0.28	0.24	0.21	0.19	0.17	0.15	0.13
	b) present value	-8.70	1.18	1.04	0.91	0.80	0.70	0.62	0.54	0.48	0.42	0.37	0.33	0.29	0.25	0.22	0.20	0.38
	c) NPV	0.03																
	3. At 15%																
	a) discount factor	1.00	0.87	0.76	0.66	0.57	0.50	0.43	0.38	0.33	0.28	0.25	0.21	0.19	0.16	0.14	0.12	0.11
	b) present value	-8.70	1.16	1.01	0.88	0.77	0.67	0.58	0.50	0.44	0.38	0.33	0.29	0.25	0.22	0.19	0.16	0.32
	c) NPV	-0.55																
	4. At 40%																
	a) discount factor	1.00	0.71	0.51	0.36	0.26	0.19	0.13	0.09	0.07	0.05	0.03	0.02	0.02	0.01	0.01	0.01	0.00
	b) present value	-8.70	0.96	0.68	0.49	0.35	0.25	0.18	0.13	0.09	0.06	0.05	0.03	0.02	0.02	0.01	0.01	0.01
	c) NPV	-5.36																
E.	**Cash flow (credit for barbojo-bagasse)**	Years 0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
	All figures are in MM = thousands																
1	**Quantities**																
1.1	Ethanol @ 90% capacity		14.00	14.00	14.00	14.00	14.00	14.00	14.00	14.00	14.00	14.00	14.00	14.00	14.00	14.00	14.00	
1.2	Fertilizer @ 3.7 usg per usg of ethanol		51.78	51.78	51.78	51.78	51.78	51.78	51.78	51.78	51.78	51.78	51.78	51.78	51.78	51.78	51.78	
1.3	Bagsse @ 300Kg/tc																	
1.4	Barbojo 330 kg/tc																	
2	**Cash inflows**																	
2.1	Revenue from hydrous ethanol	0.00	7.56	7.56	7.56	7.56	7.56	7.56	7.56	7.56	7.56	7.56	7.56	7.56	7.56	7.56	7.56	
2.2	Credit revenue from fertilizer sale	0.00	0.39	0.39	0.39	0.39	0.39	0.39	0.39	0.39	0.39	0.39	0.39	0.39	0.39	0.39	0.39	
2.3	Liquidation of plant																	3.00
2.4	Credit value of Barbojo	0.00	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	

2.5	Credit value of bagasse	0.00	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	
3	**Total cash inflows**	0.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	
4	**Cash outflows**																	
4.1	Investments	8.70																
4.2	Annual costs - fixed		0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	
4.3	Annual costs - variable		6.58	6.58	6.58	6.58	6.58	6.58	6.58	6.58	6.58	6.58	6.58	6.58	6.58	6.58	6.58	
5	**Total cash outflow**	8.70	6.61	6.61	6.61	6.61	6.61	6.61	6.61	6.61	6.61	6.61	6.61	6.61	6.61	6.61	6.61	
6	**Net cash outflow**	-8.70	2.39	2.39	2.39	2.39	2.39	2.39	2.39	2.39	2.39	2.39	2.39	2.39	2.39	2.39	2.39	3.00
F.	**Net present value**																	
	1. At 8%																	
	a) discount factor	1.00	0.926	0.857	0.794	0.735	0.681	0.63	0.583	0.54	0.5	0.463	0.429	0.397	0.368	0.34	0.315	0.292
	b) present value	-8.70	2.21	2.05	1.90	1.76	1.63	1.51	1.39	1.29	1.19	1.11	1.02	0.95	0.88	0.81	0.75	0.88
	c) NPV	12.62																
	2. At 12%																	
	a) discount factor	1.00	0.893	0.797	0.712	0.636	0.567	0.507	0.452	0.404	0.361	0.322	0.287	0.257	0.229	0.205	0.183	0.163
	b) present value	-8.70	2.13	1.90	1.70	1.52	1.36	1.21	1.08	0.96	0.86	0.77	0.69	0.61	0.55	0.49	0.44	0.49
	c) NPV	8.06																
	3. At 15%																	
	a) discount factor	1.00	0.87	0.756	0.658	0.572	0.497	0.432	0.376	0.327	0.284	0.247	0.215	0.187	0.163	0.141	0.123	0.107
	b) present value	-8.70	2.08	1.81	1.57	1.37	1.19	1.03	0.90	0.78	0.68	0.59	0.51	0.45	0.39	0.34	0.29	0.32
	c) NPV	5.59																
	4. At 26.9%																	
	a) discount factor	1.00	0.788	0.621	0.489	0.386	0.304	0.239	0.189	0.149	0.117	0.092	0.073	0.057	0.045	0.036	0.028	0.022
	b) present value	-8.70	1.88	1.48	1.17	0.92	0.73	0.57	0.45	0.36	0.28	0.22	0.17	0.14	0.11	0.09	0.07	0.07
	c) NPV	0.00																
	5. At 40%																	
	a) discount factor	1.00	0.714	0.51	0.364	0.26	0.186	0.133	0.095	0.068	0.048	0.035	0.025	0.018	0.013	0.009	0.006	0.005
	b) present value	-8.70	1.71	1.22	0.87	0.62	0.44	0.32	0.23	0.16	0.12	0.08	0.06	0.04	0.03	0.02	0.02	0.01
	c) NPV	-2.75																

	Worksheet 5	**INTEGRATED BIORESOURCE ENERGY PROJECT**															
		With reference to the proposed project at the Bernard Lodge factory															
	All figures in thousands																
	e.g. 1,000,000 = 1.0																
	If buissness as usual in energy and agricultural sector																
	Kingston area	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**
A.	**Investments**																
1	Oil or coal fired power plant	121.19															
2	Using existing sugar factory	11.20															
3	Using existing hydrous &																
	anhydrous ethanol facility																
4	Petrojam	3.00															
5	Petronol	3.00															
6	Total	138.38															
B.	**Base price**																
1	Oil ($ / barrel)	20															
2	Sugar ($ / ton)	393.525		608	EEC price												
				470	US price												
3	Ethanol ($ / usgallon)	0.90															
C.	**Cash inflow into Jamaica**																
	by export BLF, Petrojam																
	Cash inflow																
1	Sugar export revenue at		15.74	15.74	15.74	15.74	15.74	15.74	15.74	15.74	15.74	15.74	15.74	15.74	15.74	15.74	15.74
	subisdised price																
2	Revenue from ethanol at		18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00
	subsidised price																
3	Revenue from molasses		2.03	2.03	2.03	2.03	2.03	2.03	2.03	2.03	2.03	2.03	2.03	2.03	2.03	2.03	2.03
	at $80/ton																
	Total cash inflow	0	35.77	35.77	35.77	35.77	35.77	35.77	35.77	35.77	35.77	35.77	35.77	35.77	35.77	35.77	35.77
D.	**Cash outflow from Jamaica**																
	by import																
	Cash outflow																
1	Total investment	138.38															
2	Oil import by JPS for power		12.23	12.60	12.97	13.36	13.76	14.18	14.60	15.04	15.49	15.96	16.43	16.93	17.44	17.96	18.50
	generation ($ 20/ barrels)																
3	For gasoline - if no ethanol		4.00	4.12	4.24	4.37	4.50	4.64	4.78	4.92	5.07	5.22	5.38	5.54	5.70	5.87	6.05
	blending (10% by volume)																
4	EEC wet ethanol feedstock		11.34	22.73	22.73	22.73	22.73	22.73	22.73	22.73	22.73	22.73	22.73	22.73	22.73	22.73	22.73

	Total cash outflow	138.38	27.57	39.45	39.95	40.47	41.00	41.55	42.11	42.69	43.29	43.91	44.54	45.20	45.87	46.57	47.28
E.	**Net cash outflow**	-138.38	8.20	-3.68	-4.18	-4.70	-5.23	-5.78	-6.35	-6.93	-7.53	-8.14	-8.78	-9.43	-10.11	-10.80	-11.51
1	At 15%																
2	Discount factor	1	0.87	0.76	0.66	0.57	0.50	0.43	0.38	0.33	0.28	0.25	0.21	0.19	0.16	0.14	0.12
3	Discounted cash flow	-138.38	7.13	-2.785	-2.751	-2.688	-2.602	-2.499	-2.385	-2.264	-2.139	-2.013	-1.887	-1.763	-1.642	-1.526	-1.41512
4	**NPV**	-161.61															
	SCENARIO 1	**(If subsidy on the price of sugar and ethanol price is removed)**															
		(If the oil price falls to $ 15 / barrels)															
A.	**Base prices**																
1	Oil	15	$/barrel														
2	Sugar	266	$/ton														
3	Ethanol	0.55	$/usg														
B.	**Cash inflow into Jamaica by export**																
	Cash inflow																
1	Sugar revenue at market price		10.64	10.64	10.64	10.64	10.64	10.64	10.64	10.64	10.64	10.64	10.64	10.64	10.64	10.64	10.64
2	Revenue from ethanol at market price		11.00	11.00	11.00	11.00	11.00	11.00	11.00	11.00	11.00	11.00	11.00	11.00	11.00	11.00	11.00
3	Revenue from molasses at $80/ton		2.03	2.03	2.03	2.03	2.03	2.03	2.03	2.03	2.03	2.03	2.03	2.03	2.03	2.03	2.03
	Total cash inflow	0	23.67	23.67	23.67	23.67	23.67	23.67	23.67	23.67	23.67	23.67	23.67	23.67	23.67	23.67	23.67
C.	**Cash outflow from Jamaica by import**																
	Cash outflow																
1	Total investment	138.38															
2	Oil import by JPS for power generation ($ 20/ barrels)		12.23	12.60	12.97	13.36	13.76	14.18	14.60	15.04	15.49	15.96	16.43	16.93	17.44	17.96	18.50
3	For gasoline - if no ethanol blending (10% by volume)		4.00	4.12	4.24	4.37	4.50	4.64	4.78	4.92	5.07	5.22	5.38	5.54	5.70	5.87	6.05
4	EEC wet ethanol feedstock		11.34	22.73	22.73	22.73	22.73	22.73	22.73	22.73	22.73	22.73	22.73	22.73	22.73	22.73	22.73
	Total cash outflow	138.38	27.57	39.45	39.95	40.47	41.00	41.55	42.11	42.69	43.29	43.91	44.54	45.20	45.87	46.57	47.28
D.	**Net cash outflow**	-138.38	-3.90	-15.78	-16.29	-16.80	-17.33	-17.88	-18.45	-19.03	-19.63	-20.24	-20.88	-21.53	-22.21	-22.90	-23.62
1	At 15%																
2	Discount factor	1	0.32	1.67	1.79	1.93	2.08	2.24	2.43	2.63	2.86	3.12	3.41	3.74	4.11	4.52	5.00
3	Discounted cash flow	-138.38	-1.24	-26.41	-29.23	-32.41	-36.02	-40.11	-44.78	-50.10	-56.19	-63.17	-71.20	-80.46	-91.18	-103.60	-118.07
4	**NPV**	-982.54															
	SCENARIO 2	(If the proposed alternative technology is introduced without increasing sugar or ethanol production															
	Kingston area																

		0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
A.	**Base price**																
1	Oil ($ / barrel)	15															
2	Sugar ($ / ton	266															
3	Ethanol ($ / usg)	0.55															
B.	**Investments**																
1	BIG/ISTIG (biomass fired)	96.74															
2	Using existing sugar factory	11.20															
3	Using existing hydrous																
	ethanol facility																
	Petrojam	3.00															
	Petronol	3.00															
4	Total	113.94															
C.	**Cash inflow into Jamaica**																
	by export																
	Cash inflow																
1	Sugar revenue at market		10.64	10.64	10.64	10.64	10.64	10.64	10.64	10.64	10.64	10.64	10.64	10.64	10.64	10.64	10.64
	price																
2	Revenue from ethanol at		11.00	11.00	11.00	11.00	11.00	11.00	11.00	11.00	11.00	11.00	11.00	11.00	11.00	11.00	11.00
	market price																
3	Revenue from molasses		2.03	2.03	2.03	2.03	2.03	2.03	2.03	2.03	2.03	2.03	2.03	2.03	2.03	2.03	2.03
	at $80/ton																
	Total cash inflow	0	23.67	23.67	23.67	23.67	23.67	23.67	23.67	23.67	23.67	23.67	23.67	23.67	23.67	23.67	23.67
D.	**Cash outflow from Jamaica**																
	by import																
	Cash outflow																
1	Total investment	113.94															
2	Oil import by JPS for power		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	generation																
3	For gasoline - if no ethanol		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	blending (10% by volume)																
5	EEC wet ethanol feedstock	113.94	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Total cash outflow																
E.	**Net cash outflow**	-114	23.67	23.67	23.67	23.67	23.67	23.67	23.67	23.67	23.67	23.67	23.67	23.67	23.67	23.67	23.67
1	At 15%																
2	Discount factor	1	0.87	0.76	0.66	0.57	0.50	0.43	0.38	0.33	0.28	0.25	0.21	0.19	0.16	0.14	0.12
3	Discounted cash flow	-113.94	20.58	17.89	15.56	13.53	11.77	10.23	8.90	7.74	6.73	5.85	5.09	4.42	3.85	3.34	2.91
4	NPV	24.44															

	Worksheet 6	**INTEGRATED BIORESOURCE ENERGY PROJECT**															
	All figures in thousands	From the viewpoint of the whole economy															
	E.g. 1,000,000 = 1.0																
	If buissness as usual in energy and agricultural sector																
A	**Kingston area**	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**
B	**Base price**																
1	Oil ($/barrel)	20															
2	Sugar ($/ ton)	393.5															
3	Ethanol ($/usg)	0.90															
C	**Investments**																
1	Oil or coal fired power plant	121.19															
2	Using existing sugar factory	11.20															
3	Using existing hydrous																
	ethanol facility																
	Petrojam	3.00															
	Petronol	3.00															
4	Total	138.38															
B.	**Cash inflow into**																
	Jamaica by export																
	Cash inflow																
1	Sugar revenue @ $604/ton		93.40	93.40	93.40	93.40	93.40	93.40	93.40	93.40	93.40	93.40	93.40	93.40	93.40	93.40	93.40
	subisdised price																
2	Revenue from ethanol at		18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00
	subsidised price of $.90/usg																
3	Revenue from molasses		8.78	8.78	8.78	8.78	8.78	8.78	8.78	8.78	8.78	8.78	8.78	8.78	8.78	8.78	8.78
	at $80/ton																
	Total cash inflow	0	120.18	120.18	120.18	120.18	120.18	120.18	120.18	120.18	120.18	120.18	120.18	120.18	120.18	120.18	120.18
C.	**Cash outflow from**																
	Jamaica by import																
	Cash outflow																
1	Total investment	138.4															
2	Oil import by JPS for power		82.00	84.46	86.99	89.60	92.29	95.06	97.91	100.85	103.88	106.99	110.20	113.51	116.91	120.42	124.03
	generation ($ 20/ barrels)																
3	Oil import by bauxite		146.00	146.00	146.00	146.00	146.00	146.00	146.00	146.00	146.00	146.00	146.00	146.00	146.00	146.00	146.00
	industry ($20/barrels)																
4	For gasoline ($ 20/barrels)		40.00	41.20	42.44	43.71	45.02	46.37	47.76	49.19	50.67	52.19	53.76	55.37	57.03	58.74	60.50

5	For automotive - marine		52.00	53.56	55.17	56.82	58.53	60.28	62.09	63.95	65.87	67.85	69.88	71.98	74.14	76.36	78.65
	$ 20/ barrel																
6	Coal import		3.65	3.65	3.65	3.65	3.65	3.65	3.65	3.65	3.65	3.65	3.65	3.65	3.65	3.65	3.65
	Total cash outflow	138.4	323.65	328.87	334.25	339.79	345.49	351.37	357.42	363.65	370.07	376.68	383.49	390.51	397.73	405.18	412.84
D.	**Net cash outflow**	-138	-203	-209	-214	-220	-225	-231	-237	-243	-250	-257	-263	-270	-278	-285	-293
1	At 15%																
2	Discount factor	1	0.87	0.76	0.66	0.57	0.50	0.43	0.38	0.33	0.28	0.25	0.21	0.19	0.16	0.14	0.12
3	Discounted cash flow	-138.4	-176.9	-157.8	-140.8	-125.6	-112	-99.95	-89.19	-79.59	-71.03	-63.4	-56.6	-50.53	-45.11	-40.28	-35.97
4	NPV	-1483															
	SCENARIO 1 (If subsidy on the price of sugar and ethanol price is removed)																
A.	**Base price**																
1	Oil	15	$/barrel														
2	Sugar	266	$/ton														
3	Ethanol	0.55	$/usg														
B.	**Cash inflow**																
1	Sugar revenue @ $266/ton		63.13	63.13	63.13	63.13	63.13	63.13	63.13	63.13	63.13	63.13	63.13	63.13	63.13	63.13	63.13
	market price																
2	Revenue from ethanol at		11.00	11.00	11.00	11.00	11.00	11.00	11.00	11.00	11.00	11.00	11.00	11.00	11.00	11.00	11.00
	market price of $.55/usg																
3	Revenue from molasses		8.78	8.78	8.78	8.78	8.78	8.78	8.78	8.78	8.78	8.78	8.78	8.78	8.78	8.78	8.78
	at $80/ton																
	Total cash inflow	0	82.92	82.92	82.92	82.92	82.92	82.92	82.92	82.92	82.92	82.92	82.92	82.92	82.92	82.92	82.92
C.	**Cash outflow from**																
	Jamaica by import																
	Cash outflow																
1	Total investment	138.4															
2	Oil import by JPS for power		61.50	63.35	65.25	67.20	69.22	71.30	73.43	75.64	77.91	80.24	82.65	85.13	87.68	90.31	93.02
	generation ($ 15/barrels)																
3	Oil import by bauxite		109.50	109.50	109.50	109.50	109.50	109.50	109.50	109.50	109.50	109.50	109.50	109.50	109.50	109.50	109.50
	industry ($15 / barrels)																
4	For gasoline ($ 15/barrels)		30.00	30.90	31.83	32.78	33.77	34.78	35.82	36.90	38.00	39.14	40.32	41.53	42.77	44.06	45.38
5	For automotive - marine		39.00	40.17	41.38	42.62	43.89	45.21	46.57	47.97	49.40	50.89	52.41	53.99	55.60	57.27	58.99
	$ 15/ barrel																
6	Coal import		3.65	3.65	3.65	3.65	3.65	3.65	3.65	3.65	3.65	3.65	3.65	3.65	3.65	3.65	3.65
	Total cash outflow	138.4	243.65	247.57	251.60	255.75	260.03	264.44	268.98	273.65	278.47	283.43	288.53	293.79	299.21	304.80	310.55
D.	**Net cash outflow**	-138	-161	-165	-169	-173	-177	-182	-186	-191	-196	-201	-206	-211	-216	-222	-228
1	At 15%																
2	Discount factor	1	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60
3	Discounted cash flow	-138.4	-96.48	-98.83	-101.2	-103.7	-106.3	-109	-111.7	-114.5	-117.4	-120.3	-123.4	-126.6	-129.8	-133.2	-136.6
4	NPV	-1867															

		0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
	Scenario 2 (If the proposed alternative technology is introduced)																
	Kingston area	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
A.	**Investments**																
1	BIG/ISTIG (biomass fired)	96.74			**Base price**												
2	Using existing sugar factory	11.20															
3	Using existing hydrous			1	Oil	15	$/barrel										
	ethanol facility			2	Sugar	266	$/ton										
	Petrojam	3.00		3	Ethano	0.55	$/usg										
	Petronol	3.00															
4	Total	113.94															
B.	**Cash inflow into**																
	Jamaica by export																
	Cash inflow																
1	Sugar revenue at market		63.13	63.13	63.13	63.13	63.13	63.13	63.13	63.13	63.13	63.13	63.13	63.13	63.13	63.13	63.13
	price																
2	Revenue from ethanol at		11.00	11.00	11.00	11.00	11.00	11.00	11.00	11.00	11.00	11.00	11.00	11.00	11.00	11.00	11.00
	market price																
3	Revenue from molasses		8.78	8.78	8.78	8.78	8.78	8.78	8.78	8.78	8.78	8.78	8.78	8.78	8.78	8.78	8.78
	at $80/ton																
	Total cash inflow	0	82.92	82.92	82.92	82.92	82.92	82.92	82.92	82.92	82.92	82.92	82.92	82.92	82.92	82.92	82.92
C.	**Cash outflow from**																
	Jamaica by import																
	Cash outflow																
1	Total investment	138.4															
2	Oil import by JPS for power		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	generation																
3	Oil import by bauxite		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	industry																
4	For gasoline		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5	For automotive - marine		39.00	40.17	41.38	42.62	43.89	45.21	46.57	47.97	49.40	50.89	52.41	53.99	55.60	57.27	58.99
	$ 20/ barrel																
6	Coal import		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Total cash outflow	138.4	39.00	40.17	41.38	42.62	43.89	45.21	46.57	47.97	49.40	50.89	52.41	53.99	55.60	57.27	58.99
D.	**Net cash outflow**	-138	43.92	42.75	41.54	40.30	39.02	37.71	36.35	34.95	33.51	32.03	30.50	28.93	27.31	25.64	23.93
1	At 15%																
2	Discount factor	1	0.87	0.76	0.66	0.57	0.50	0.43	0.38	0.33	0.28	0.25	0.21	0.19	0.16	0.14	0.12
3	Discounted cash flow	-138.4	38.19	32.32	27.31	23.04	19.4	16.3	13.66	11.43	9.526	7.918	6.557	5.408	4.439	3.624	2.94
4	**NPV**	83.69															